STEPHEN HAWKING

INSIDE THE THESIS THAT BROKE THE INTERNET

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Why our chances of finding another habitable world are better than ever

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BREATHTAKING IMAGES
FUTURE TECH
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SPACE BEER

Why a Space Station brew is more important than you think

SOMETHING SHOOK UP THE UNIVERSE

...and it wasn't gravity

RETURN TO ROSETTA'S COMET

JIM AL-KHALILI ANSWERS *YOUR* QUESTIONS

FUTURE
DIGITAL EDITION
ISSUE 075

Artist's impression of CAESAR collecting a sample from 67P

@ Adrian Mann

Welcome

As I write this, our next exoplanet mission is making its way to the launch pad to be lofted into space by SpaceX. The Transiting Exoplanet Survey Satellite (TESS) is our next venture in finding a planet just like our own, and the team behind the NASA mission think that it's going to revolutionise our hunt for Earth 2.0 like never before. Turn to page 16 for a flavour of what we can look forward to when it opens its eyes to the universe.

Also this month, if you've ever read through the thesis of world-renowned physicist Stephen Hawking but aren't sure of what it all means, then this is the issue for you - we've broken it down, giving you the ultimate bluffer's guide to the research that broke the internet... Or, more specifically, took Cambridge University's website down.

We also head to the International Space Station to discover that there's a brewery of sorts on the Earth-orbiting platform. But it's not made so that astronauts can sit back, relax and sip on an alcoholic beverage after a tough day of space research - barley seeds from none other than Budweiser could help us in our manned mission to Mars. As now-retired astronaut Clayton Anderson once said, "a successful mission will include many key components, including the need to provide crew members with commodities that remind them of home." And that's where space beer fits right in.

Gemma Lavender
Editor

"Comets hold a wealth of information about the ingredients required to make a Solar System" **Page 50**

Our contributors include...

Colin Stuart
Astronomer & author
Colin delivers Stephen Hawking's groundbreaking thesis in a nutshell. Delve into the ultimate bluffer's guide for an inside look into Hawking's mind.

Natalie Starkey
Planetary scientist & author
We're going back to Rosetta's comet! Natalie finds out why we need to go back and sending a sample return mission in the process.

Lee Cavendish
Staff Writer & astronomer
Lee reveals the real reason why Budweiser is brewing beer in space and why it's much more important than you could ever imagine.

Abigail Beall
Space science writer
There's a force that shaped the universe - and it's not gravity. Abigail meets the researchers who have discovered that a magnetic force has been at work before our time.

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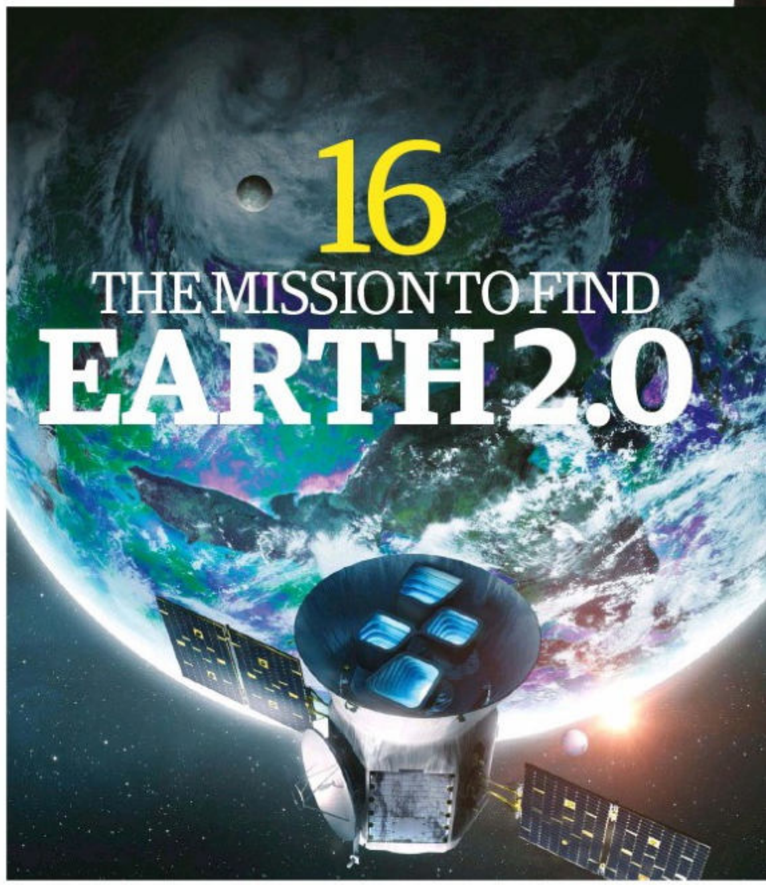
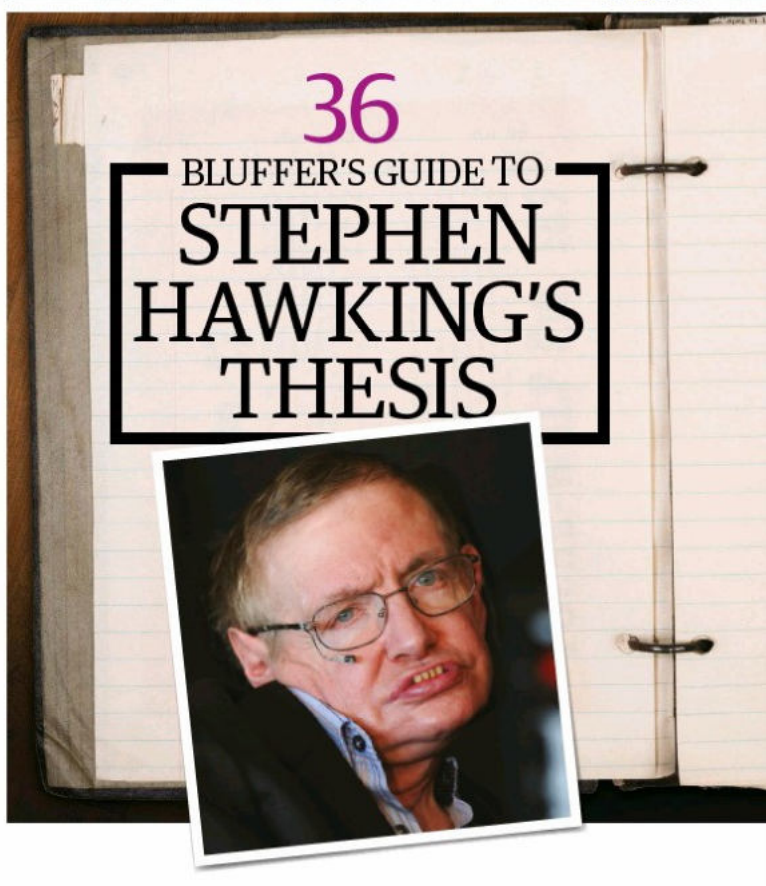
LAUNCH PAD
YOUR FIRST CONTACT WITH THE UNIVERSE



FEATURES



"There is certainly a need for a new fundamental theory in order to unify the two big frameworks"

STARGAZER

Your complete guide to the night sky

LAUNCH PAD

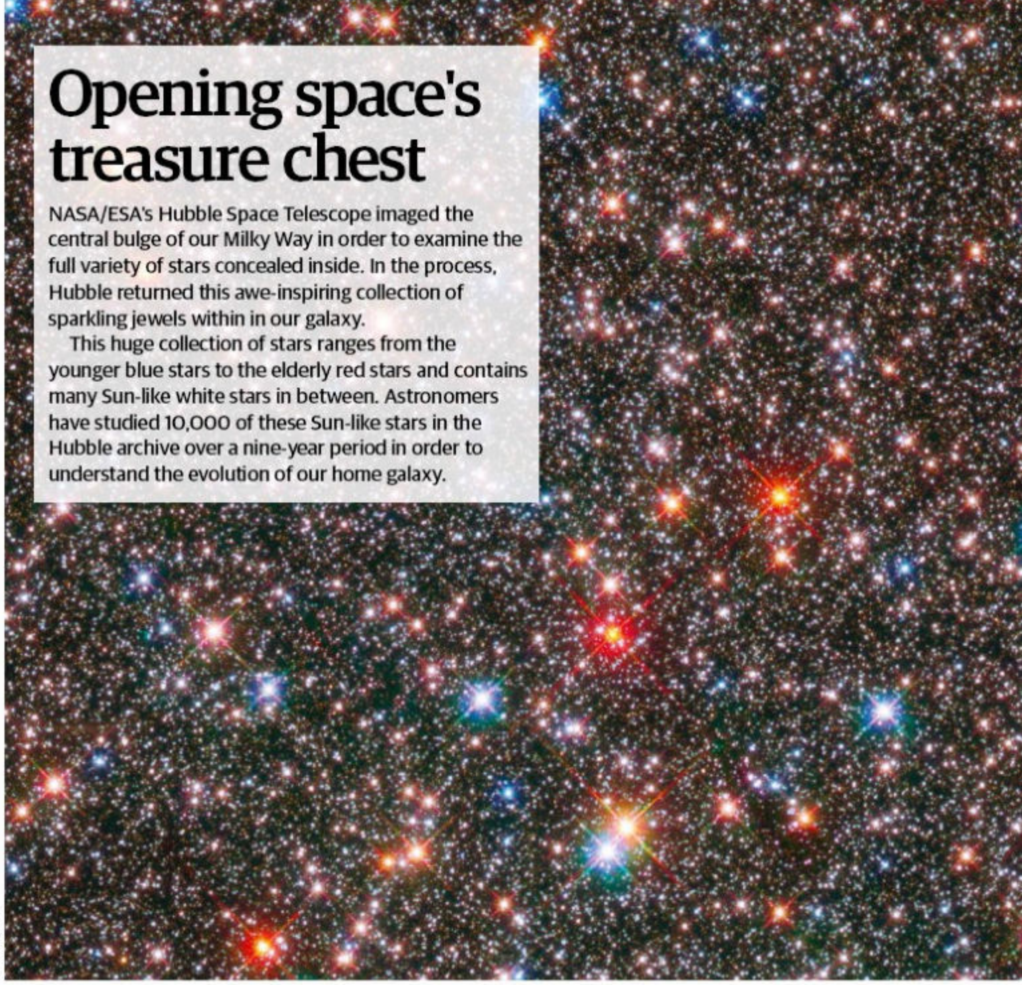
YOUR FIRST CONTACT WITH THE UNIVERSE

Supermoon peeps over a Chilean mountain

Peering over the beautiful Cerro Armazones Mountain in Chile is an equally beautiful supermoon. A supermoon occurs when the Moon reaches its closest point to Earth – also referred to as its perigee – during its fuller phase, causing it to appear 14 per cent larger than normal.

The road zig-zagging its way to the top of the mountain leads to the construction site of the European Southern Observatory's Extremely Large Telescope (ELT). When the ELT is finally built it will be the world's largest optical instrument, with an enormous primary mirror size of 39 metres (128 feet).

© G.Hüdepohl/ ESO



Opening space's treasure chest

NASA/ESA's Hubble Space Telescope imaged the central bulge of our Milky Way in order to examine the full variety of stars concealed inside. In the process, Hubble returned this awe-inspiring collection of sparkling jewels within in our galaxy.

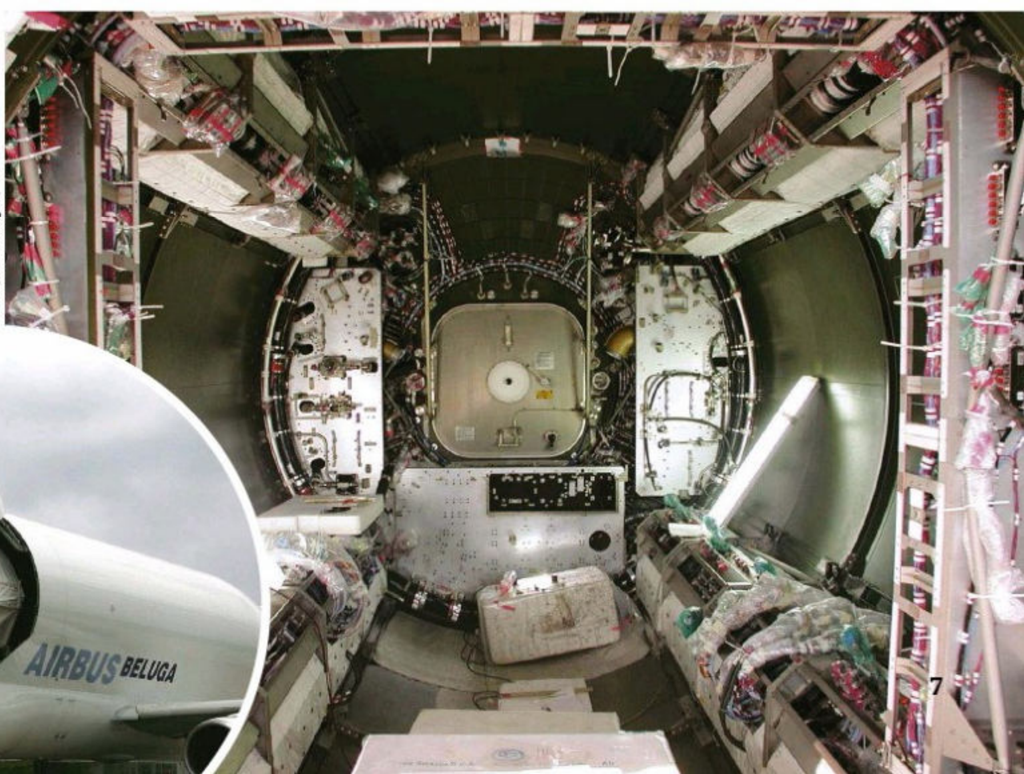
This huge collection of stars ranges from the younger blue stars to the elderly red stars and contains many Sun-like white stars in between. Astronomers have studied 10,000 of these Sun-like stars in the Hubble archive over a nine-year period in order to understand the evolution of our home galaxy.

© NASA, ESA

Celebrating a decade of the European Columbus laboratory

The European Columbus laboratory has been part of the prestigious International Space Station (ISS) for ten years now. The module has provided a safe and comfortable environment for astronauts to conduct unique experiments in microgravity.

Columbus arrived in the United States in 2006 on board a Beluga aircraft, Airbus A300 (inset). The module was finally launched from the Kennedy Space Centre in Florida in February 2008 after five years of delays and problems. The Columbus laboratory is the smallest module on the ISS, but it still provides the same payload volume, power, data retrieval, vacuum and venting services as the other modules.

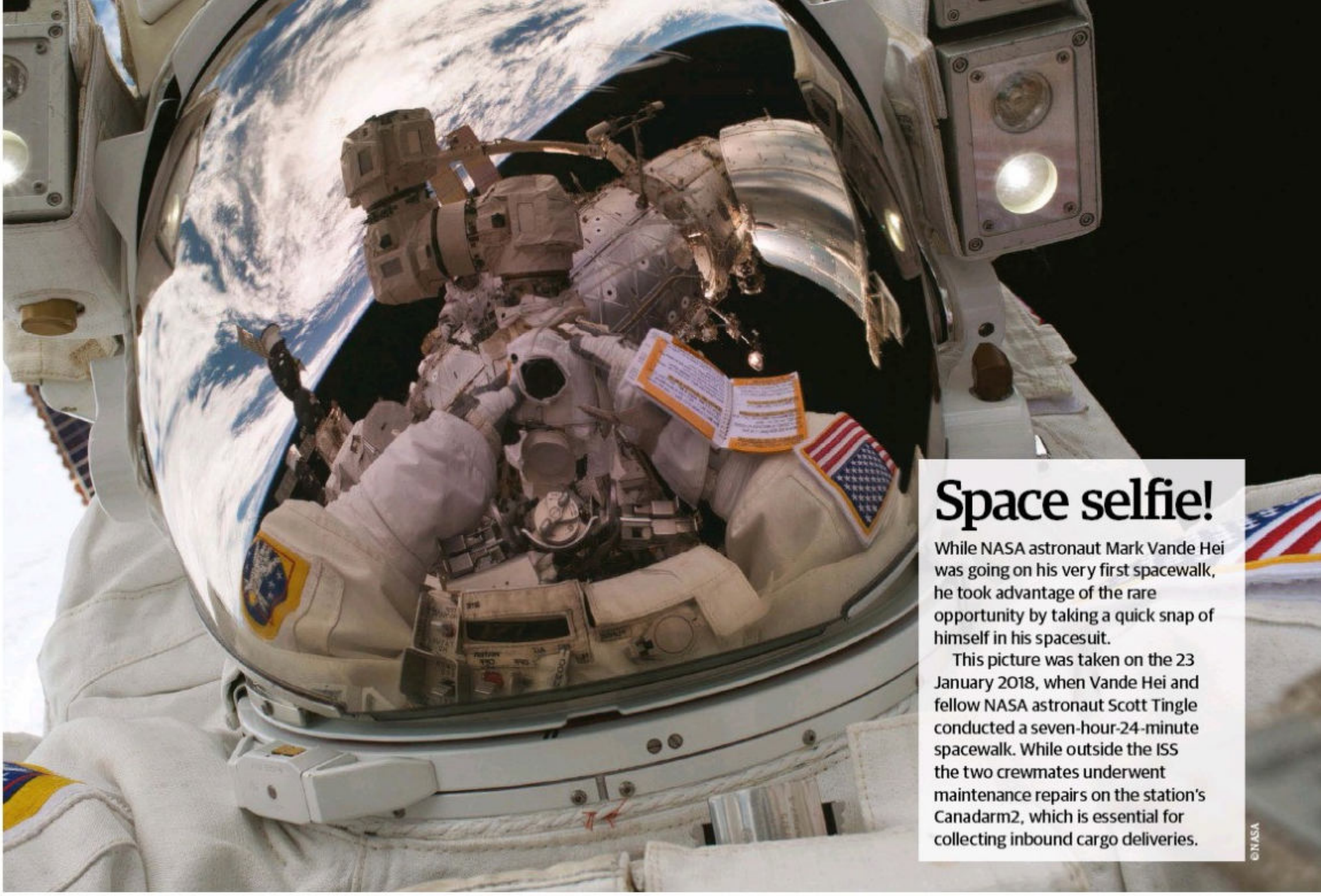


© ESA; EADS-I. Vagner

Peering into the cosmic zoo

NASA's Spitzer and Hubble space telescopes have captured a cosmic penguin protecting its egg. By combining the infrared and visible light of this region, astronomers can see how the duo have been deformed due to their gravitational attraction.

The penguin, also known as NGC 2936, and the egg, NGC 2937, are two galaxies that have been caught up in each other's gravity and are slowing merging. Eventually the two galaxies will collide and come together, kick-starting an abundance of new star formation.



Space selfie!

While NASA astronaut Mark Vande Hei was going on his very first spacewalk, he took advantage of the rare opportunity by taking a quick snap of himself in his spacesuit.

This picture was taken on the 23 January 2018, when Vande Hei and fellow NASA astronaut Scott Tingle conducted a seven-hour-24-minute spacewalk. While outside the ISS the two crewmates underwent maintenance repairs on the station's Canadarm2, which is essential for collecting inbound cargo deliveries.

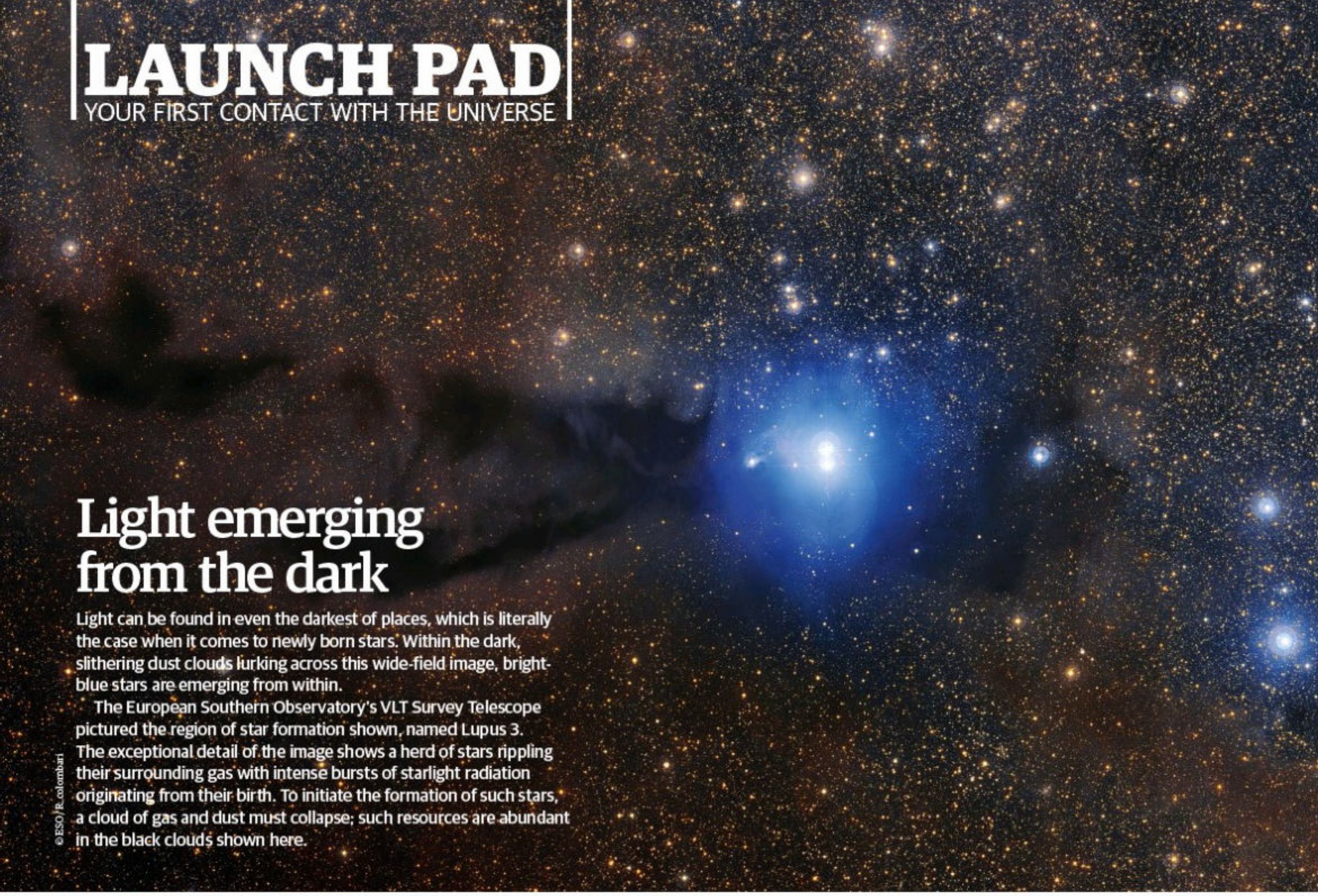
© NASA

Hunting for supernovae

45-million-light-years away in the constellation of Pegasus, a star in the galaxy NGC 7331 reached the end of its life and exploded as a spectacular supernova. Astronomers wanted to get a look at this supernova, labelled SN2014C, before it faded away. For this reason, they turned NASA/ESA's Hubble Space Telescope to the scene of its demise.

Hubble's Wide Field Camera 3 (WFC3) snapped this glorious shot of the spiral galaxy, with SN2014C faintly placed near the galaxy's core as a tiny red dot. As the galaxy faces us partially edge-on, we can see the amazing contrast between the billions of stars mixed with the dark splodges of dust interfering with the starlight.

©NASA/ESA



Light emerging from the dark

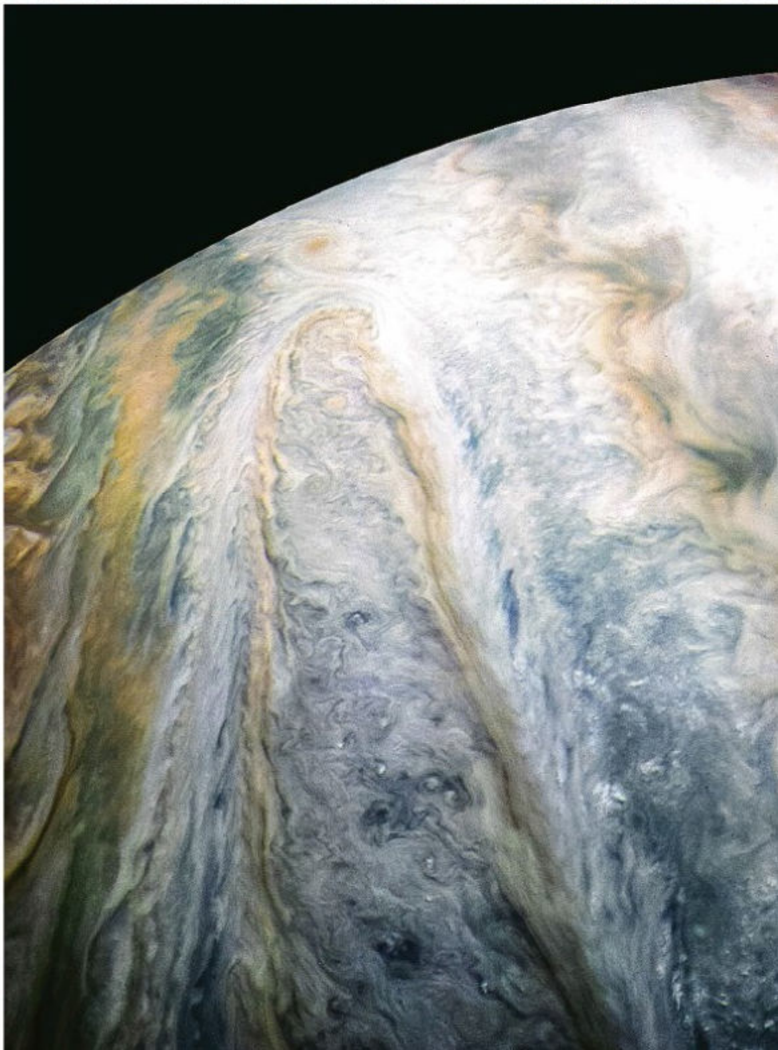
Light can be found in even the darkest of places, which is literally the case when it comes to newly born stars. Within the dark, slithering dust clouds lurking across this wide-field image, bright-blue stars are emerging from within.

The European Southern Observatory's VLT Survey Telescope pictured the region of star formation shown, named Lupus 3. The exceptional detail of the image shows a herd of stars rippling their surrounding gas with intense bursts of starlight radiation originating from their birth. To initiate the formation of such stars, a cloud of gas and dust must collapse; such resources are abundant in the black clouds shown here.

Eroding the surface of Mars

The Red Planet is a dry, dangerous and dusty place, as we can see from these images taken by NASA's Mars Reconnaissance Orbiter (MRO). The Shalbatana Valles, a prominent channel that cuts through Xanthe Terra, is a region that has supposedly been sculpted by running water.

The layers in this area are thought to have been the result of extensive erosion which most likely occurred in a period where the landscape was mostly sedimentary rock. This analysis supports the theory that a long time ago water ran on the surface of Mars and therefore could still be there, hidden beneath the surface.



©Lockheed Martin Space

Getting ready for a Martian landing

NASA's Interior Exploration using Seismic Investigation, Geodesy and Heat Transport (InSight) Mars lander will probe the interior of the Red Planet's surface. It hopes to answer vital questions regarding the formation of the terrestrial worlds of the Solar System and their evolution over the last 4 billion years.

Before its launch in May 2018, intense testing will be conducted at the Lockheed Martin clean room in Littledon, Colorado, United States. The most important test is the landing configuration and the opening of the solar panels - without them, the lander is essentially redundant, so engineers must make sure they can perform effortlessly when the time comes.

© NASA/JPL-Caltech

Spying on the south side of Jupiter

As Juno entered its tenth close flyby of Jupiter, also called a perijove, the installed JunoCam got to work, snapping as many pictures as possible before it went away for another 53 days. The JunoCam captured this picture of Jupiter's southern hemisphere, leaving it to the public to make it majestic. Citizen scientist Kevin M. Gill did exactly that, as he created this colour-enhanced image emphasising Jupiter's dynamic clouds and storms. At the time of the image the Juno spacecraft was flying just 13,604 kilometres (8,453 miles) above the top of Jupiter's erratic clouds.

SpaceX triumphantly launches its powerful new rocket

The 70-metre Falcon Heavy cleared its pad and sent a Tesla sports car towards the asteroid belt

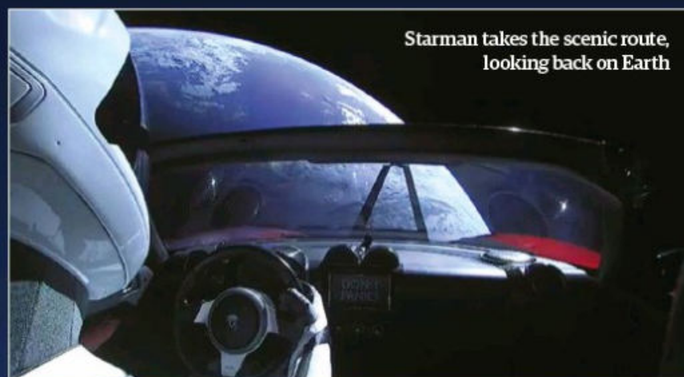
SpaceX has realised a long-held dream by finally launching the world's most powerful rocket. Elon Musk's private aerospace manufacturer sent the huge reusable launch vehicle skywards from Florida's Kennedy Space Center at 3:45pm Eastern Time on 6 February. It was quickly hailed a success, despite a problem with one of the boosters, and now the company reckons it will go on to revolutionise future space travel.

Falcon Heavy is an impressive three-core rocket that has 27 engines - the most used by any working rocket. The engines provide more than five million pounds of thrust at lift off, which is equivalent to 18 Boeing 747 aeroplanes. This allows the spacecraft to carry up to 63,500 kilograms (140,000 pounds) of cargo into lower Earth orbit or 16,780 kilograms (37,000 pounds) to Mars. In the case of this launch, it ensured it could not only carry Musk's $100,000 cherry-red Tesla Roadster car, but also a dummy in the driver's seat, appropriately named Starman.

This added a level of theatre to an already amazing occasion, watched by an estimated 100,000 people around the launch site and millions more at home. Footage shows the Heavy leaving the launchpad and soaring to the upper reaches of the Earth's atmosphere. After three minutes, the rocket's boosters detached before two of them successfully touched down at the same time at Cape Canaveral Air Force Station.

It later emerged that the central booster had failed to return to Earth, missing a drone ship in the Atlantic Ocean by 100 metres (328 feet) and instead exploding as it "hit the water at 300 miles per hour". That was seen as a blow for SpaceX since it was the key component of the Heavy vehicle, although Musk said there had never been any plans to reuse it. However, the mere fact that it didn't explode on the launchpad was astonishing enough; Musk admitted such a thing could easily have happened given the power of the craft.

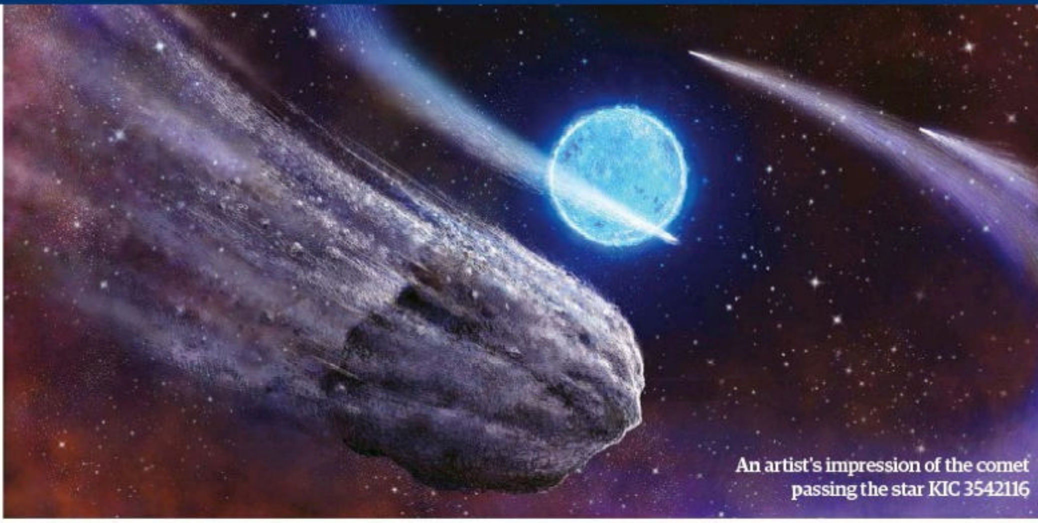
By getting it off the ground, it means the Tesla car, which looped Earth for six hours and has the words "Don't Panic" inscribed on the dashboard, will end up orbiting the Sun for many years to come. It also allows SpaceX to gear up for two more launches this year, each of which costs around $90 million - less than that of its competitors (the United Launch Alliance's Delta IV Heavy costs around $400 million to launch). "An exciting future lies ahead," Musk says.



Starman takes the scenic route, looking back on Earth

> "This added a level of theatre to an already amazing occasion"

As the rocket made its way through the Van Allen Belt, the Starman dummy on board was 'listening' to David Bowie's *Life on Mars*


An artist's impression of the comet passing the star KIC 3542116

© NASA/ Danielle Futselaar

Comet found passing by a distant star

An amateur astronomer picking through Kepler's data discovered patterns that pointed to the presence of exocomets

Researchers have discovered evidence of comets in another star system by observing dips in the intensity of light from a star. It marks the first time such small objects have ever been detected in this way. Even more remarkable is that the discovery was first made by a citizen scientist called Thomas Jacobs.

The exocomets were picked up using the sensitive Kepler Space Telescope - a spacecraft that's already well known to be capable of detecting Earth-like planets around Sun-like stars. It spotted tiny dark objects passing between the dwarf star KIC 3542116 and Earth, and the observations matched expectations of a comet's journey.

The researchers picked out the comet's tail and found it blocked just one tenth of a per cent of KIC 3542116's light. The objects passed by six times between 2009 and 2013. The star also dimmed deeply three times, with the star slowly regaining its brightness over the course of a day. Whether or not that was an indication of six comets passing by or a cluster involving some that passed multiple times is not known, however.

While that means there is no certainty over the number of comets spotted - it could be just one, but the orbit suggests not - there is no doubt that they are the smallest objects ever discovered passing in front of a star in another planetary system.

"It's amazing that something several orders of magnitude smaller than the Earth can be detected just by the fact that it's emitting a lot of debris," says Professor Saul Rappaport of MIT's Kavli Institute.

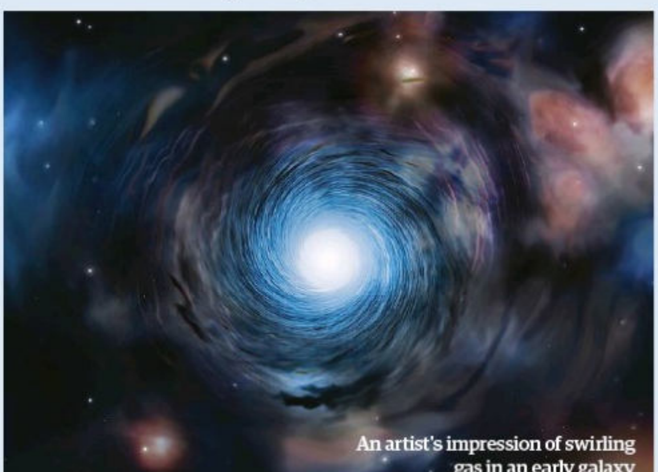
Swirling gas detected in the earliest galaxies

Astronomers discover that the youngest structures spin in the same way as the much more mature Milky Way

An international team of astronomers have looked back nearly 13 billion years and found two small 'newborn' galaxies that spin like a whirlpool in a similar manner to more mature galaxies such as the Milky Way. Rather than be "dynamically messy due to the havoc caused by exploding young stars," Dr Renske Smit from the University of Cambridge says, "these mini-galaxies show the ability to retain order and appear well regulated."

This means that, despite their small size, the galaxies are already rapidly growing to become an adult galaxy of the type we are living in today, the researchers say. The discovery is also the first time normal star-forming galaxies and their movement have been identified at a very early stage in cosmic history - just 800 million years after the Big Bang - albeit in far-infrared wavelengths.

Such observations have been made possible thanks to the


An artist's impression of swirling gas in an early galaxy

© Astronomy Institute, Amanda Smith

ESO's Atacama Large Millimeter/submillimeter Array (ALMA) in Chile, which allows scientists to analyse the spectral 'fingerprint' of the far-infrared light it collects to work out the distance to the galaxies. By being able to essentially cut through a haze of neutral hydrogen gas, which makes observing through optical telescopes difficult, it lets them see the internal motion of the gas that fuelled their growth. The astronomers say the data "paves the way for larger studies of galaxies during the first billion years of cosmic time".

Space News in Brief

Cosmonauts break spacewalk record

Expedition 54 cosmonauts Alexander Misurkin and Anton Shkaplerov have completed the longest Russian spacewalk, having spent eight hours and 14 minutes tackling an upgrade to the communications system on their side of the International Space Station.

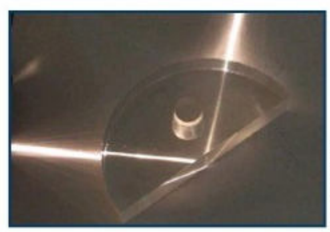

© NASA

Poop can grow food

By pumping waste into cylinders that act as microbial reactors, it has been shown that microbes can break down urine and faeces, extracting components that can be used to help grow edible bacteria. The process would make good use for astronaut's waste and help provide them with food on deep-space missions.

Attempt to slow light

Physicists are looking at ways of slowing light from its top speed of 186,000 miles per second and even stop it at the exceptional point when two mirroring, complex wavelength patterns meet and merge. They say the beams of light could be tuned to stop it moving at such a point.


© Friedrich Graf

Space may be infected

A team of scientists believe viruses may be spread across space - potentially providing evidence of life away from Earth. They say space agencies should be looking out for viruses since they form a crucial part of life on our planet, although they admit the technology to do so is still being developed.

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Dust storms on Mars are linked to gas escape

Scientists have found that rising air during global dust storms causes water vapour in the middle atmosphere to increase

Global dust storms on Mars could play an important role in the ongoing process of gas escaping from the Red Planet's atmosphere, scientists have found. A new study, which took a fresh look at the observations made by NASA's Mars Reconnaissance Orbiter during the most recent large-scale dust storm in 2007, noted water vapour moving to a higher altitude, roughly 50 to 100 kilometres (30 to 60 miles) high.

Water vapour also increased in volume by more than a hundredfold. "We found there's an increase in water vapour in the middle atmosphere in connection with dust storms," said Nicholas Heavens of Hampton University, Virginia, United States. "Water vapour is carried up with the same air mass rising with the dust." This phenomenon would have contributed to Mars' transformation from a wet, warmer planet to the frozen, arid Mars we see today.

Researchers are now hoping for another global dust storm to allow for closer testing of their hypothesis. "It would be great to have a global dust storm we could observe with all the assets now at Mars, and that could happen this year," said David Kass of NASA's Jet Propulsion Laboratory, Pasadena.

The idea that atmospheric hydrogen escapes into space, causing a rise in middle-atmosphere water volume has also been observed by ESA's Mars Express orbiter and NASA's Hubble Telescope. The next global dust storm season is expected this summer, lasting into early 2019. Past ones have taken place in 1977, 1982, 1994, 2001 and 2007.

These images from 2001 show the change in Mars' appearance when dust-storm haze is globally distributed

Weirdly-blowing winds on swollen exoplanet challenge scientists

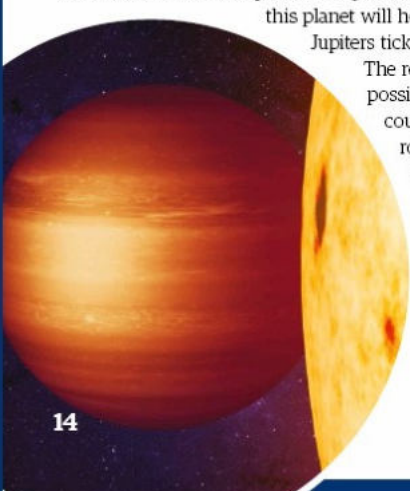
Fresh questions are being asked about the atmospheric physics of hot Jupiters following a 'curveball' finding

Scientists are looking to explain why the hottest spot on the exoplanet CoRoT-2b is not in its expected location. Instead of being towards the east of its equator, it is actually west of centre. That points to the winds blowing in the opposite direction to other short-orbit gas giant exoplanets.

CoRoT-2b is at a distance of 930 light years from Earth towards the constellation Aquila. It takes three days to complete an orbit around its parent star making it incredibly hot, particularly so on the side facing that star. Until new data was collected from NASA's Spitzer Space Telescope, scientists assumed there would be strong eastward winds.

"We've previously studied nine other hot Jupiter giant planets orbiting super close to their star. In every case, they have had winds blowing to the east, as theory would predict," says Nicolas Cowan, a researcher at both the McGill Space Institute and the Institute for Research on Exoplanets. "But now, nature has thrown us a curveball. On this planet, the wind blows the wrong way. Since it's often the exceptions that prove the rule, we are hoping that studying this planet will help us understand what makes hot Jupiters tick."

The researchers are considering three possibilities. One suggests the planet could be spinning so slowly that a single rotation takes longer than a full orbit of the star. Another hypothesises the planet's atmosphere is interacting with its magnetic field while the third potential is that large clouds covering the eastern side of the planet make it appear darker.



An artist's impression of hot winds on a hot Jupiter exoplanet

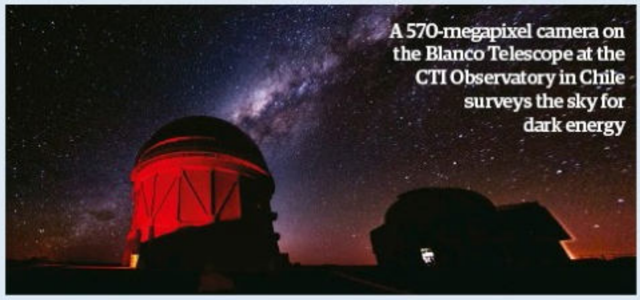
New stellar streams are discovered around the Milky Way

Close to a dozen stars ripped away from smaller systems around our galaxy have been detected

Exactly 11 new streams of stars from other galaxies have been detected around our galaxy. They were discovered while astronomers were surveying the skies to uncover the nature of dark energy and dark matter. "It's exciting that we found so many stellar streams," said astrophysicist Alex Drlica-Wagner of the Fermilab Center for Particle Astrophysics.

Before this discovery by the Dark Energy Survey (DES), only 24 or so stellar streams had ever been picked up. The stars are attracted by the Milky Way's powerful gravitational pull on smaller, nearby galaxies; the stars form streams as they are torn away.

"We're interested in these streams because they teach us about the formation and structure of the Milky Way and its dark-matter halo. Stellar streams give us a snapshot of a larger galaxy being built out of smaller ones," adds University of Chicago graduate student Nora Shipp. "These discoveries are possible because DES is the widest, deepest and best-calibrated survey out there."



A 570-megapixel camera on the Blanco Telescope at the CTI Observatory in Chile surveys the sky for dark energy

THIS MISSION WILL FIND EARTH 2.0

NASA's new planet-hunting satellite will revolutionise our understanding of planets around other stars – and statistics suggest that it should find some worlds very similar to ours

Written by Giles Sparrow

The search for 'exoplanets' - worlds orbiting distant stars - has come a long way since the first such objects were confirmed in the mid-1990s. Today thousands of alien worlds are known or suspected, with each new satellite or technique offering fresh insights, which leads to the detection of many new planets. However, fundamental questions remain unanswered, and our experiments produce discoveries that are inevitably biased towards certain type of planets that are easy to detect.

Now, a small satellite, the Transiting Exoplanet Survey Satellite (TESS), promises to look at the sky in a whole new way, which could finally answer some key questions - particularly when it comes to small planets like Earth. Over the next two years, the team behind TESS hope that it will create the most comprehensive catalogue so far of planets orbiting bright and nearby stars.

TESS has been a long time coming, as Dr Stephen Rinehart, the mission's project scientist at NASA's Goddard Space Flight Center, recounts: "The project started out as an independently funded development that MIT [Massachusetts Institute of Technology] was doing with some private donors [Google in particular provided early investment]. After missing out on selection for NASA's Small Explorer satellite program in the late 2000s, the TESS team realised that the spacecraft would work better as a full-scale Explorer mission, and Goddard was brought on board."

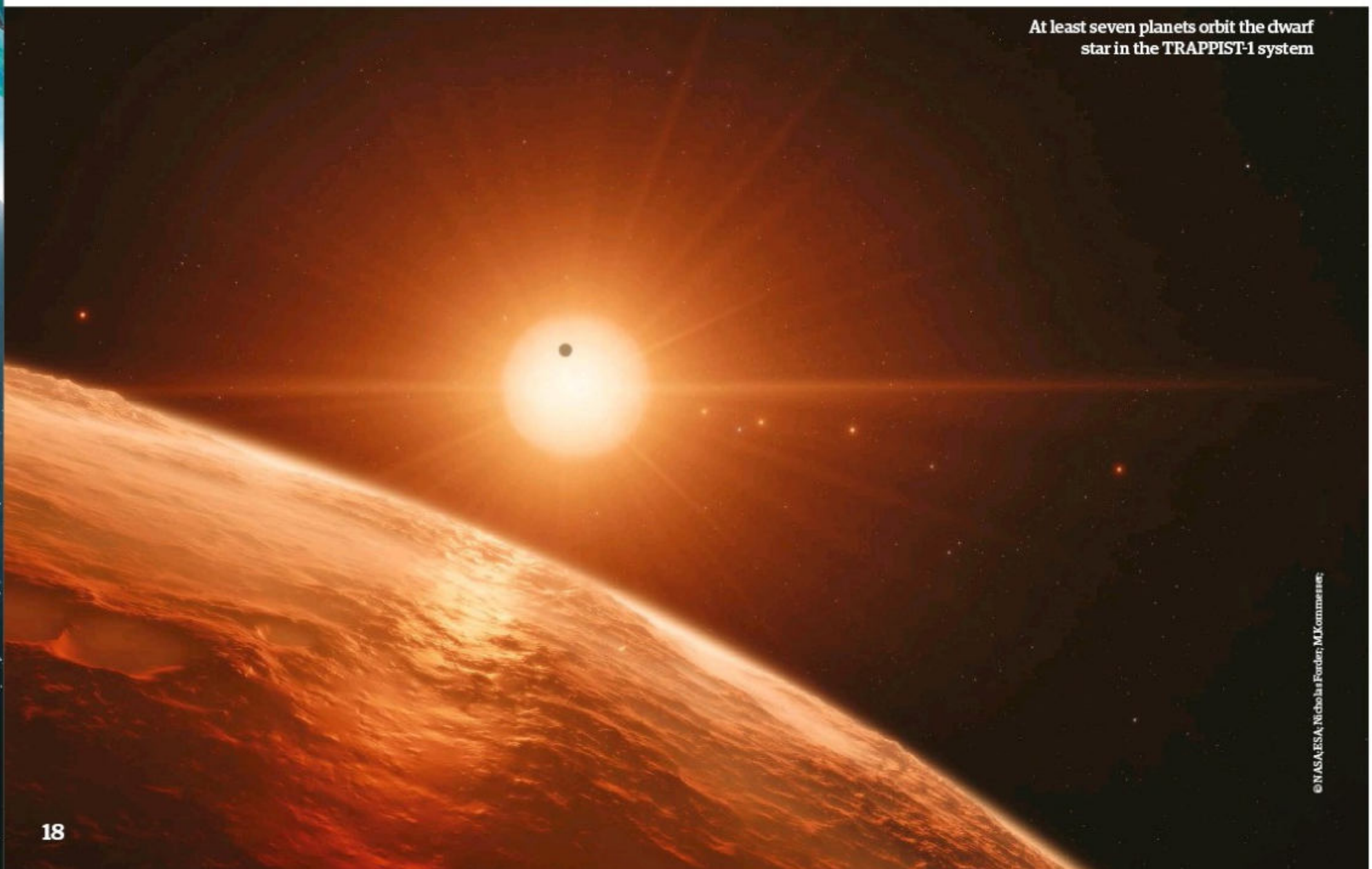
Rinehart's role involves day-to-day collaboration with the mission's principal investigator (PI), Dr George Ricker, and deputy PI Dr Roland Vanderspek, both at MIT's Kavli Institute for Astrophysics and Space Research. "Roland was actually my undergraduate thesis adviser, shall we say, a while ago," he recalls, "so I've known these guys since I was an undergrad. When Goddard got involved, it was clear that TESS needed a NASA project scientist, and George asked for me to join the team in that role. We submitted our proposal around the beginning of 2011, and in 2013 we got the go ahead to actually start building. As we speak we're two months and one day from our planned launch date."

As its name suggests, TESS will detect planets using the so-called 'transit method', measuring tiny dips in starlight created by orbiting planets. "You can see the principle at work in our own Solar System," explains Dr Rinehart. "There are some great videos of Venus transiting the Sun in 2004 and 2012. If you have a planet orbiting a star, and its orbit happens to be aligned with your line of sight, then the planet will pass in front of the star. In our Solar System that means that we can occasionally see Venus as a black dot tracking in front of the Sun. For more distant stars of course, we can't resolve the little black dot, but the planet still blocks a certain amount of light from the star - and the exact amount depends on how big the planet is."

That small amount of blocked-out light is the key not only to finding planets, but also to estimating their sizes: "If we were looking at our own Solar System from, say, ten-light-years away, if Earth passes in front of the Sun, it blocks out about 0.01 per cent of the Sun's light. Jupiter on the other hand blocks out about one per cent."

Searching for planets using the transit method involves making frequent measurements of a star's exact brightness and pinpointing moments when that brightness suddenly dips and then recovers. If the dips repeat in a regular pattern, this confirms the planet's orbital period - its year. For example, if a star dips in brightness by one per cent every 20 days, astronomers can not only tell that the exoplanet has a 20-day year, but can also estimate its size at about 1/10th the diameter of the star (and therefore blocking out 1/100th of its visible surface during transits). It's simple in principle, but requires high-precision measurements, an uninterrupted, undistorted view of the sky and lots of patience - all factors that make it a tough call for

"The next step in exoplanet research is to start characterising individual planets, not just counting them" **Stephen Rinehart**



At least seven planets orbit the dwarf star in the TRAPPIST-1 system

Evolution of an exoplanet hunter

TESS is just the latest in a series of satellites that have revolutionised our ideas about alien worlds

Kepler

Launch date: 7 March 2009
NASA's Kepler satellite was designed to carry out a long-term survey of a single area of the sky. Although a failure in its pointing mechanism led to the original mission goals being cut short, engineers redesigned the satellite to continue useful planet-hunting work. So far it has yielded over 2,000 confirmed exoplanets.

Spitzer

Launch date: 25 August 2003
This NASA spacecraft was put to work on the hunt for exoplanets after its hardware was tweaked. NASA's Sean Carey, the manager of the Spitzer Science Center at Caltech in Pasadena, California, said: "We never even considered using Spitzer for studying exoplanets... It would have seemed ludicrous back then."

TESS

Launch date: 20 March 2018 (no later than June 2018)
TESS will carry out the first comprehensive transit survey of bright stars across the sky and is predicted to discover tens of thousands of new worlds, including about 2,000 Earth-like exoplanets.

Hubble Space Telescope

Launch date: 24 April 1990
The venerable Hubble Space Telescope was the first large optical telescope in orbit. Although it was not designed to hunt for exoplanets it has laid the foundations for many of the specialised missions that have since followed. The telescope has also offered us important insights into exoplanets found by other means.

CHEOPS

Launch date: End-2018
A collaboration between the European Space Agency and Switzerland, CHEOPS (CHaracterising ExOPlanets Satellite) will use a larger telescope than TESS to target stars already known to have transiting planets, producing more accurate information about their size, density and other characteristics.

JWST

Launch date: Spring 2019
Currently scheduled for launch next year, NASA's enormous infrared space telescope and successor to Hubble should offer new insights into the way that Solar Systems form around young stars, and is expected to be able to provide direct images of many exoplanets for the first time.

WFIRST

Launch date: Mid-2020s
Now under full development by NASA, the Wide-Field Infrared Survey Telescope (WFIRST) will carry a coronograph designed to precisely block the dazzling light of stars without affecting the much fainter light of their planets. This could reveal details such as their surface temperatures, composition and atmospheric gases.

Anatomy of TESS

The satellite is built to point its cameras as precisely as possible, gather and process their data and periodically beam it back to Earth

1 Sun shade
TESS's outer sun shade protects its delicate cameras from dazzling sunlight that could damage their sensors.

2 Reaction wheels
Four spinning gyroscope wheels use the principle of action and reaction to adjust TESS's orientation and point the telescope in different directions.

3 Star tracker
This camera identifies guide stars and keeps them precisely aligned and maintain the telescope's orientation in space.

4 Antenna
The satellite's antenna sends data back to Earth at broadband-like speeds of 100 megabits per second once in every two-week orbit.

5 Master computer
TESS' onboard computer controls all the operations – targeting its cameras, acquiring images and storing data.

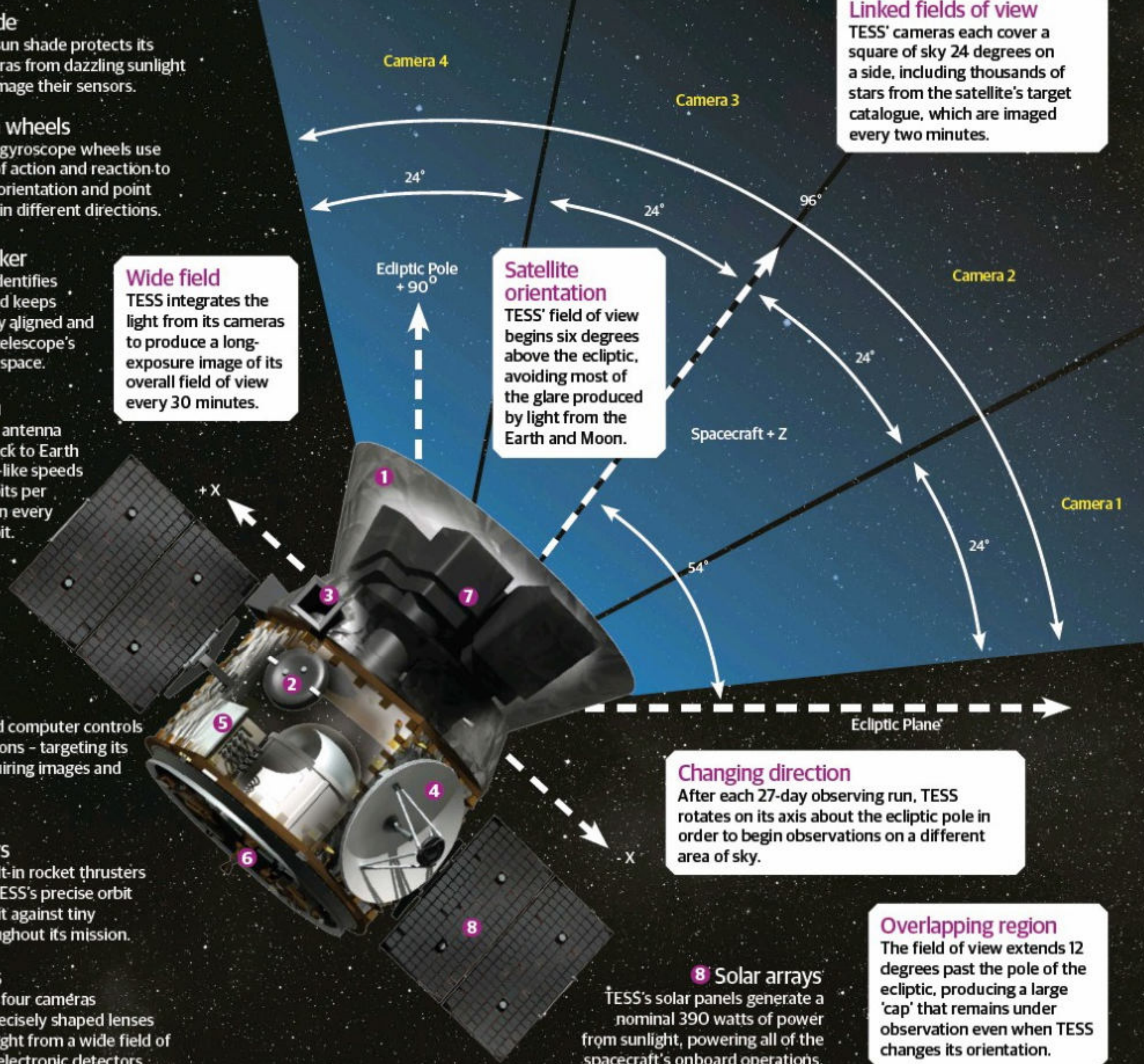
6 Thrusters
Five small built-in rocket thrusters help finalise TESS's precise orbit and maintain it against tiny changes throughout its mission.

7 Cameras
Each of TESS' four cameras uses seven precisely shaped lenses to direct starlight from a wide field of view onto its electronic detectors.

8 Solar arrays
TESS's solar panels generate a nominal 390 watts of power from sunlight, powering all of the spacecraft's onboard operations.

How it'll work

How will TESS' amazing cameras search for new exoplanets



Wide field
TESS integrates the light from its cameras to produce a long-exposure image of its overall field of view every 30 minutes.

Satellite orientation
TESS' field of view begins six degrees above the ecliptic, avoiding most of the glare produced by light from the Earth and Moon.

Linked fields of view
TESS' cameras each cover a square of sky 24 degrees on a side, including thousands of stars from the satellite's target catalogue, which are imaged every two minutes.

Changing direction
After each 27-day observing run, TESS rotates on its axis about the ecliptic pole in order to begin observations on a different area of sky.

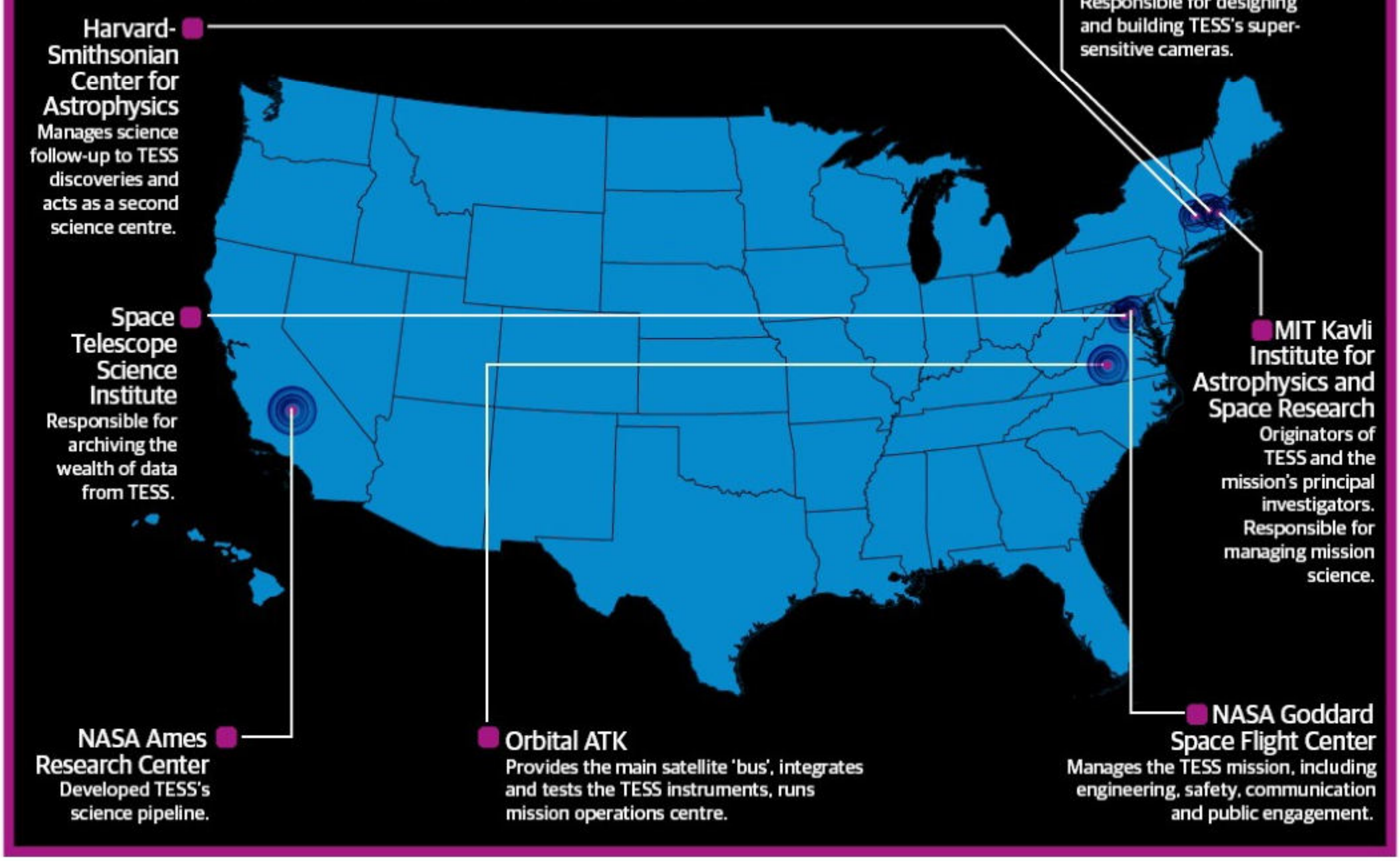
Overlapping region
The field of view extends 12 degrees past the pole of the ecliptic, producing a large 'cap' that remains under observation even when TESS changes its orientation.

TESS' targets

Earth-like planets
TESS' postage-stamp images of selected stars should capture the small changes in brightness triggered when small Earth-like planets, such as those in the TRAPPIST-1 system, pass in front of their stars.

Giant gaseous worlds
TESS' wide-field images are expected to capture up to 20,000 new transiting planets around bright stars. It has been suggested that most of these are likely to be gas giants in tight orbits around their stars, similar to HD 189733b.

Who's involved? TESS is a collaboration – but who does what?



most Earth-based telescopes, but an ideal task for orbiting satellites.

The most famous use of the transit method so far has been in NASA's hugely successful Kepler satellite. Launched in 2009, Kepler was designed to stare at a single crowded region of sky, continuously monitoring the brightness of more than 150,000 stars and looking for any tell-tale dips. Before Kepler, only a handful of exoplanets had been detected using transits - many more were known from the radial velocity (RV) technique, the first exoplanet-hunting tool to be developed in the mid-1990s.

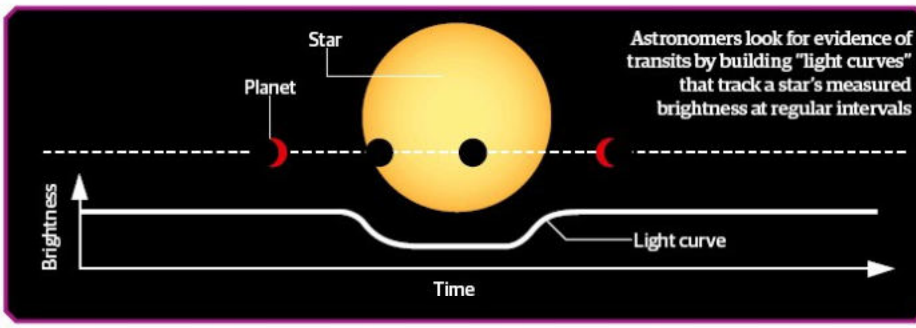
RV relies on analysing a star's rainbow-like spectrum to detect minute shifts in the wavelength of its light, created when a star with an orbiting planet is pulled slightly towards and then away from Earth by the planet's mass. Although it is biased towards detecting giant planets with enough mass to influence the movement of their star, in principle RV allows planets to be found in any size of orbit. It also provides clues to a planet's minimum mass (though not an absolute measurement on its own).

The transit method, in contrast, is biased towards planets in tight orbits around their stars - simple geometry means that the bigger a planet's orbit is, the greater the chance that the planet can circle its star while never crossing its face as seen from a given direction in space. On the other hand, transits allow astronomers to find small planets whose gravitational tug is probably too small to make an obvious impression on their star's light spectrum.

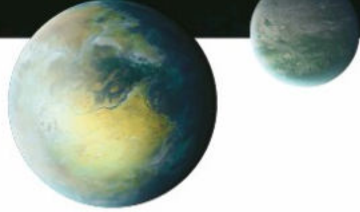
"Before Kepler, we had no idea what percentage of stars had an Earth-like planet around them," points out Dr Stephen Rinehart. "We just didn't have enough of them to reach any conclusions, because finding those small planets is really hard with the radial velocity method." Kepler's hugely successful mission, however, identified thousands of transiting planets, offering a startling insight into just how common broadly Earth-like exoplanets probably are. Inevitably, though, its success has given rise to new and even more challenging questions.

"The next step in exoplanet research is to start characterising individual planets," states Rinehart. "Not just counting them and knowing that they're there, but measuring features such as their masses

> "Before Kepler, we had no idea what percentage of stars had an Earth-like planet around them"
>
> **Stephen Rinehart**



Astronomers look for evidence of transits by building "light curves" that track a star's measured brightness at regular intervals



and perhaps even detecting their atmospheres. If you know the orbital period from transits, that can help you identify changes in the radial velocity data even if it's a really weak signal. But you still need to have a good spectrum, and for that you need relatively bright stars."

Kepler's long, deep stare across the galaxy netted a huge number of transits for its survey of the broad exoplanet population, but very few of its targets were bright enough to provide useful data when their light was smeared out by a spectroscope. As a result, the RV technique's usefulness is limited to just a handful of Kepler's discoveries.

TESS, however, takes a different approach, designed specifically to find stars that lend themselves to follow-up RV measurements and other observations. Instead of harvesting vast numbers of faint stars in a single direction, the satellite will conduct a relatively shallow survey of bright stars across the entire sky. As Rinehart explains: "We're looking for planets transiting stars within a couple of hundred light years as opposed to a couple of thousand for Kepler, so on average the stars are between 30- and 100-times brighter."

In order to carry out its survey, TESS carries a set of four cameras pointing in different directions on a single plane, like evenly spread fingers. Each camera has a 24 x 24-degree field of view (huge in astronomical terms), so together the cameras cover a field of 24 x 96 degrees at any time. Developed at MIT's Lincoln Laboratory, the cameras are relatively small, with each light-gathering lenses just ten centimetres (four inches) in diameter, but they use highly sensitive state-of-the-art detectors to deliver a pin-sharp 64-megapixel image of the sky.

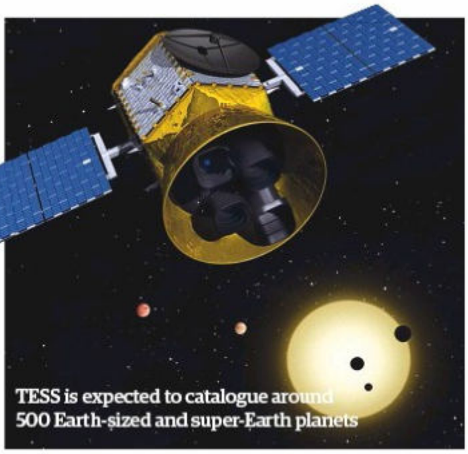
Dr Rinehart takes up the story: "When TESS is observing, it looks at a single field of view for 27 days. That field extends from six degrees above the ecliptic plane [the plane of Earth's orbit around the Sun, cluttered with nearby Solar System objects including planets and asteroids] to 12 degrees past the ecliptic pole. By tiling 13 of these observing strips over 27 days we can cover almost an entire hemisphere of the sky, including continuous coverage of the area around the pole. We start in the southern hemisphere, and then in the second year of the mission we flip around and look at the northern hemisphere. That way we cover nearly the entire sky, apart from a 12-degree band around the ecliptic itself."

TESS's onboard systems carry out the first step in turning raw camera images into useful transit-hunting data. The satellite is programmed with a catalogue of around 200,000 preselected stars, and the camera electronics extract 'postage stamps' of each target star on the list every two minutes; each orbit produces 10,000 postage stamps. Once in each 13.7-day orbit around Earth, this data is transmitted to the ground, where it can be converted into a light curve of each star's brightness over time.

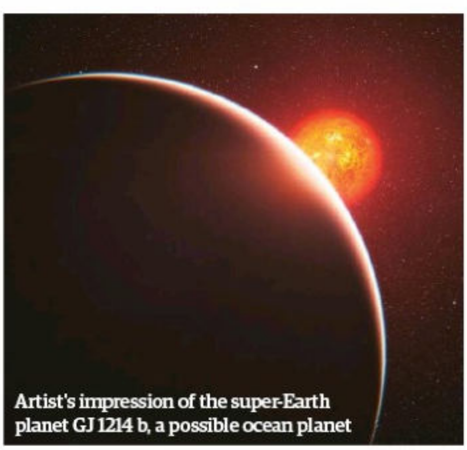
In addition, every 30 minutes the cameras deliver a long-exposure image of their entire field of view. "That data's going to be really interesting," enthuses Rinehart. "The primary goal of TESS is to find small planets, so when we select our target catalogue we're aiming for stars where we could hope to find those kinds of planets. There are certain stars, larger ones for instance, where we couldn't hope to detect an Earth-sized planet with this telescope, so we don't bother wasting the two-minute data from it, but those stars will still be on the full images."

This means that while statistics suggest the mission may find about 2,000 Earth-like planets in the postage-stamp data, the full-frame exposures could reveal another 20,000 larger planets around other stars. "With Kepler there's a limited number of planets suitable for follow-up observations, but with TESS there should be a glut," predicts Rinehart. "One of the challenges for the project is trying

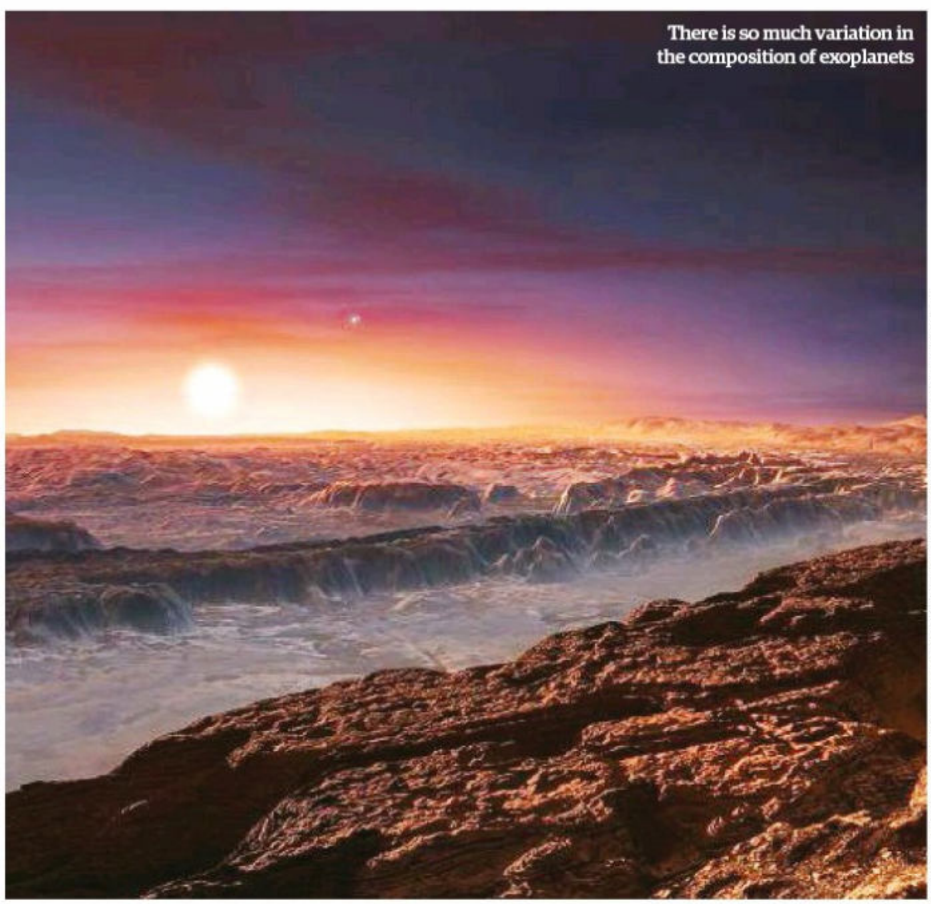
"There's the potential for TESS to produce some really interesting data about the late stages of planet-forming discs" **Stephen Rinehart**



TESS is expected to catalogue around 500 Earth-sized and super-Earth planets



Artist's impression of the super-Earth planet GJ 1214 b, a possible ocean planet



There is so much variation in the composition of exoplanets

Confirmed exoplanets that could host alien life

While TESS will find a lot more, we already have some contenders

to help organise the community for doing those follow-up observations - we don't want four people all deciding to do follow-up work on the same target at the same time!"

But while TESS's primary goal is to deliver a flood of new planetary discoveries, that's not the only reason for astronomers to look forward to it. Regular 30-minute snapshots of the sky will capture changes in the brightness and appearance of celestial objects that have nothing to do with transits. Variable and pulsating stars, repeating stellar explosions called recurrent novae and the violent cores of active galaxies are just some of the objects where TESS could help shed new light, and that's without considering the possibility of completely surprising discoveries.

"The Kepler team like to point out that half the papers generated by their mission have nothing to do with exoplanets," reflects Stephen Rinehart. "It was never planned, it's just that people in the community have gone 'Hey, there's something else cool that I can do with this data.' With TESS, there's no proprietary period - we're going to get the data out there as quickly as we can, and the astronomical community is going to be able to go to town just looking through it for new and interesting things."

As for Rinehart himself, once TESS is safely in orbit and delivering its data he's keeping an open mind as to what comes next. "Most of what I do is building stuff - my focus has always been on what questions need answering and what can I build to answer them. My primary science interests have been in star formation and the evolution of planetary systems, and I think there's the potential for TESS to produce some really interesting data about the late stages of planet-forming discs. I've not really had the time to plan out what my research programme is going to look like yet, but some people are going to do a lot of interesting stuff with that data regardless, and hopefully I'll get to be involved in it."


SpaceX's Falcon 9 rocket will launch TESS into orbit

Explorer's Guide

Eris

Forgotten in the outskirts of the Kuiper Belt, the dwarf planet could prove to be an intriguing destination

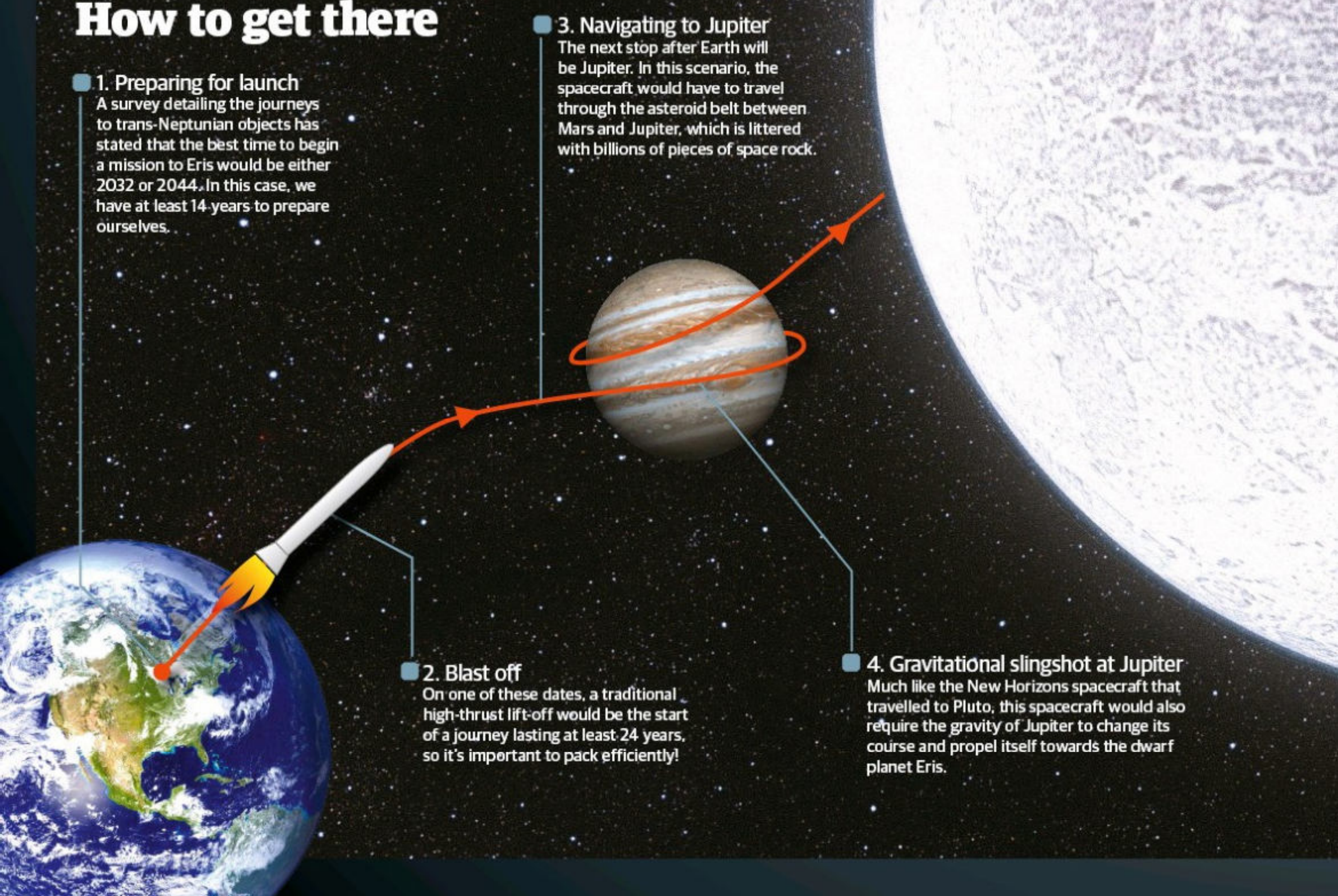
Eris, the dwarf planet named after the Greek goddess of discord and strife, has certainly caused plenty of arguments and quarrel, much like its namesake. Its discovery was confirmed in January 2005, igniting a huge debate as to what we define as a 'planet'. This led to the demotion of Pluto to a dwarf planet in 2006, so Eris could never reach the ranks of the tenth planet in the Solar System.

It can still rest its hat on the fact it's the most massive, and second-largest, dwarf planet in the Solar System. Eris exceeds Pluto's mass by around 27 per cent, but is two per cent smaller in size, meaning Eris is much denser than the former ninth planet. This density means that Eris is most likely a large rocky body covered in a relatively thin mantle of nitrogen ice, similar to Pluto; this can change as the dwarf planet travels in its orbit.

The orbit of Eris is a peculiar one; it's highly elliptical, and unlike the almost-circular orbits that all the other planets appear to adhere to. Instead, Eris has an orbit that takes 557 Earth years to complete, which reaches beyond the Kuiper Belt at its furthest point and can reach near Neptune's orbital distance at its closest approach. This drastic distance variation from the Sun supposedly causes the dwarf planet's thin atmosphere to collapse and freeze on the surface, resulting in an icy glaze with similar reflectivity to fresh snow. The surface temperature is believed to vary from about -217 degrees Celsius (-359 degrees Fahrenheit) to -243 degrees Celsius (-405 degrees Fahrenheit).

But, Eris is not alone in its journey through the Solar System, as it travels with its moon Dysnomia, named after the daughter of Eris. As of yet it hasn't had a visit from a man-made spacecraft, which is why there are only informed speculations on what the surface looks like, and its composition.

How to get there



How big is Eris?

Eris has a diameter of 2,326 kilometres (1,445 miles), making it 67 per cent the size of our Moon.

How far away is it?

As there are huge differences between the perihelion and aphelion of Eris' orbit, the closest approach between Earth and Eris leaves a 13.1-billion-kilometre (8.1-billion-mile) gap between the two. This is the rough equivalent of placing a football (soccer ball) and a squash ball 224,571 kilometres (139,542 miles) apart!

Top sights to see on Eris

There has been no visit made to Eris by a man-made spacecraft as of yet, and our telescopes are unable to decipher the true details of this elusive and dwarf planet. Scientists have only been able to estimate the properties of Eris, but what we do know does present a few opportunities for marvellous sights that wouldn't be seen on Earth.

As Eris continues on its 557-year voyage around the Sun, part of this will be through the minefield of space rock and icy bodies known as the Kuiper Belt, which lies beyond the orbit of Neptune. To see what lurks around in the darkest, coldest and most dangerous region in the Solar System would be a thrill in itself. These pieces of space rock could also prove to be the oldest material in the Solar System, answering several vital questions regarding the origins of life.

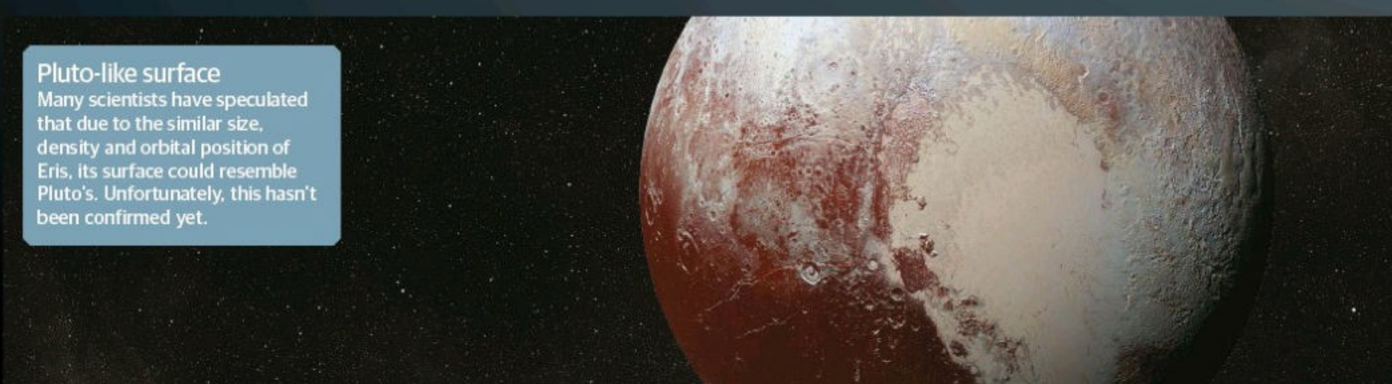
Dysnomia, the moon of Eris, is a piece of space rock gravitationally bound to the most massive dwarf planet in the Solar System. Since its discovery in 2005 by astronomers using the Keck Observatory in Mauna Kea, Hawaii, astronomers have not been able to deduce where it came from. However, they have deduced that it is about a quarter the size of Eris and it completes one orbit every 16 days. When measuring the albedo - the measure of reflectivity of sunlight - of Dysnomia, astronomers deduced it has an albedo over four-times less than Eris, meaning it has a much darker surface. This would mean that only upon closer inspection of the lone moon would we be able to unveil exciting and transformative information.

The surface of the dwarf planet has been heavily studied since its discovery, but its true nature has not been fully revealed, although some clues have arisen that could lead to an interesting discovery about Eris. For instance, due to its similar, but denser, physical properties, as well as the fact it is a trans-Neptunian object (TNO), astronomers believe it could physically resemble Pluto. It is possible that nitrogen ice covers the surface, which is what gives it the much shinier surface than Dysnomia.

Recent studies have even suggested that there could be some sort of cryovolcanism occurring on Eris that replenishes the surface. This occurrence has raised the question of what is powering this geological activity. Scientists have suggested that it could be radioactive rocks near the core which are heating the interior and causing the volcanoes to erupt frozen nitrogen.

Dysnomia
As Eris has just the one follower on its travels throughout the Solar System, the elusive moon, Dysnomia, could present some exhilarating new sights.

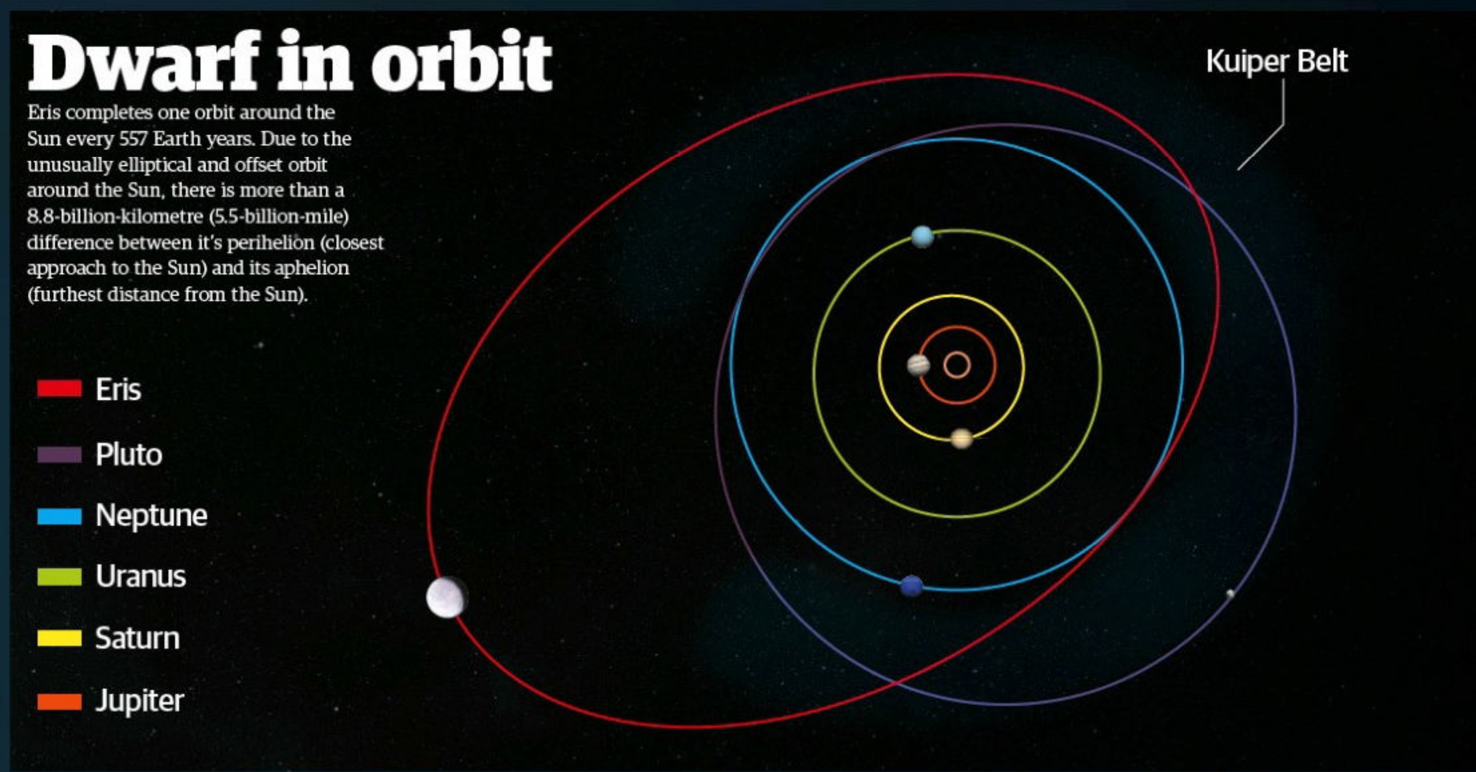
Kuiper Belt
Eris makes the trip through the far-out Kuiper Belt in its orbit. This belt contains the oldest comets and asteroids left over from the formation of the Solar System.



Pluto-like surface
Many scientists have speculated that due to the similar size, density and orbital position of Eris, its surface could resemble Pluto's. Unfortunately, this hasn't been confirmed yet.

Dwarf in orbit

Eris completes one orbit around the Sun every 557 Earth years. Due to the unusually elliptical and offset orbit around the Sun, there is more than a 8.8-billion-kilometre (5.5-billion-mile) difference between it's perihelion (closest approach to the Sun) and its aphelion (furthest distance from the Sun).



Eris in numbers

Eris' weather

-243°C
-405°F

Get ready for a cold trip! Due to the vast distance between the dwarf planet and the Sun, its surface temperature reaches temperatures as low as -243 degrees Celsius (-405 degrees Fahrenheit). This causes the atmosphere to freeze on the surface, but it will begin to thaw as it gets closer to the Sun.

97x

How much further away from the Sun it is compared to Earth at its aphelion

2003

The year that Eris was first observed

1

Number of moons orbiting Eris

25.9

The time - in hours - it takes Eris to complete one rotation of the Sun

0.43

The eccentricity of Eris' orbit

9th

Most massive known object orbiting the Sun

16

Earth days for Dysnomia to orbit Eris

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INTERVIEW BIO

Jim Al-Khalili

Born on 20 September 1962 in Baghdad, Iraq, Jim relocated to the United Kingdom in 1979. He has had a long-standing attachment to maths and physics and a desire to answer the fundamental questions of the universe. This determination is what has since led him to become the professor of physics at the University of Surrey, where he holds a chair in the Public Engagement in Science. Jim has become a popular scientific figure in the public eye due to his fantastic television documentaries for the BBC and his many books, including the recently released *What's Next?*

Jim was appointed Officer of the Order of the British Empire (OBE) in the 2008 Birthday Honours

Your interview with Jim Al-Khalili

The popular author, broadcaster and theoretical physicist has taken your questions this month

Interviewed by Lee Cavendish

The Cassini spacecraft crashed into Saturn's atmosphere in September 2017

Can the cost of space exploration be justified? *Tina Raistrick*

Yes, absolutely it can. I know that some might argue that if we are spending public taxes on scientific research, then why don't we focus it on more immediate challenges such as tackling climate change, or antimicrobial resistance, or finding cures for cancer and so on. People seem to think that space missions are a luxury, but I would come at it from a different direction.

Firstly, many space exploration missions in the future will be privately funded or a collaborative effort between many countries. Secondly, I would suggest we compare how much it costs to fund a space mission with how much many countries spend on defence. In any case, this is more than just curiosity driven blue-sky research. Space missions help us develop new technologies that then get used in so many unexpected ways.

Ultimately, for me as a scientist, space exploration is about answering some of the deepest questions, such as whether there is life elsewhere in the universe. If we stop seeking answers to questions such as this then that takes away from our very humanity.

With the recent discovery of water ice on Mars, is it possible we'll discover (at least microbial) life there very soon? *Scott W*

I am not sure about soon. Many scientists have argued that we will not be able to get a definitive answer to this question until we send a human mission to Mars. Also, robotic explorers, like NASA's Curiosity rover, can only scratch the surface and cannot do the careful digging down to search for fossil evidence of ancient microbial life there.

That's the issue. We are almost certain there is no life, even simple microbial life, on Mars today. It's a dead planet. Billions of years ago it was much more Earth-like and could have supported life, so this life would only exist in fossil form.

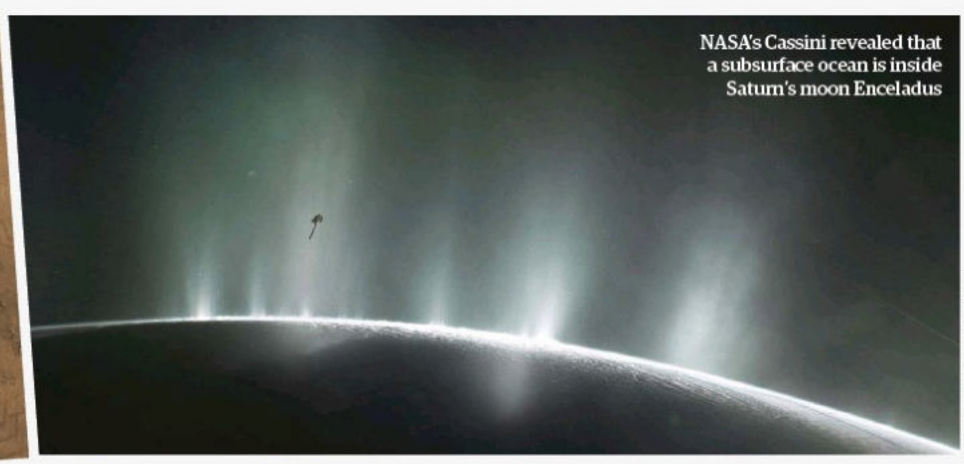
The only hope of life still being there today is if it is deep in the rocks and far from the harmful radiation on the surface. Again, though, to find this requires humans on Mars. So, we're talking a couple of decades away I feel.

Do you have a favourite space exploration mission (for example Voyager, Curiosity, Cassini)? *Rebecca Smith*

I guess I would have to say NASA's Cassini mission. The images it sent back of Saturn, its rings and its moons were breathtaking. My favourite bit of science that we have learnt from the mission has to be the exciting discoveries made from the flybys of the small moon Enceladus. This moon turns out to have liquid water under its icy surface because Cassini spotted jets of water vapour and organic material shooting out of its south pole, generating tremendous excitement that this tiny moon might be able to support microbial life.

Liquid water means it's warm under the icy crust,

"Space exploration is about answering some of the deepest questions, such as whether there is life elsewhere"



NASA's Cassini revealed that a subsurface ocean is inside Saturn's moon Enceladus

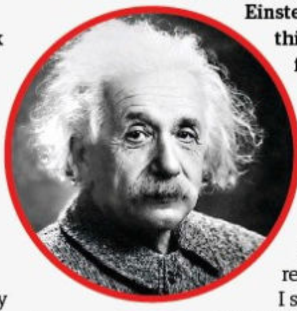
© NASA/ JPL-Caltech; Adrian Mann;

and so must have a source of energy inside it (kept going by Saturn's magnetic field). So the ingredients necessary for life are all there (energy, liquid water, organic molecules - the building blocks of life). Whether there really is microbial life there, as there might be under the Jovian moon Europa's icy surface, we have yet to find out.

In your book *What's Next?* you talk about teleportation. With the news of Chinese astronomers successfully transporting an object from Earth to a satellite in space, does this count as a major step forward in being able to teleport a human?
Keith Moriarty
Unfortunately, no. It is certainly an important scientific advance, but only really in terms of our ability to use quantum entanglement for a new kind of encryption that is going to prove very useful in the future. Particularly when quantum computers come online and are able to crack the current 'public key' encryption method we currently use to safeguard, for example, our credit card details online.

You see the Chinese result is more about how far apart two photons can be and still remain entangled. This is a very, very, very far cry from entangling the trillions of atoms necessary to make up a human. Much as we would like to have the *Star Trek* transporter room realised, it's not going to happen in our lifetime.

> "Much as we would like to have the *Star Trek* transporter room realised, it's not going to happen in our lifetime"



As quantum teleportation disagrees with Einstein's theory of relativity, do you think there is the need for a new fundamental theory?
Dean Zammit
Well, there is certainly a need for a new fundamental theory in order to unify the two big frameworks describing reality: quantum mechanics and Einstein's general theory of relativity.

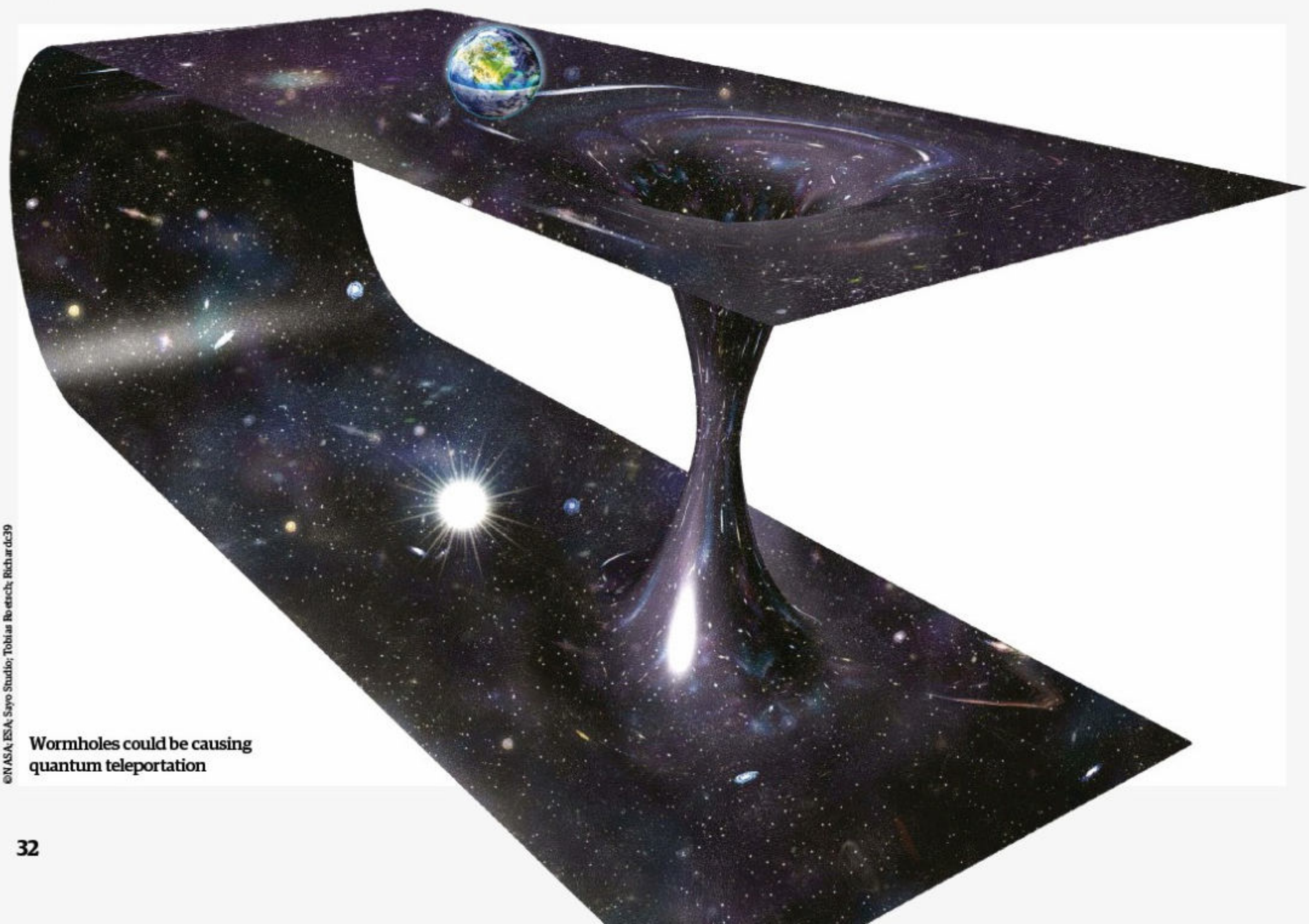
I suppose quantum teleportation highlights this in a very direct way and is the reason Einstein hated entanglement, calling it 'spooky action at a distance'. However, there is a glimmer of hope. Recent research has suggested there may in fact be a very profound link between entanglement/teleportation and the predictions of general relativity.

In 1935, Einstein published two seemingly unconnected papers. One [of the papers was] on the problems with entanglement violating speed-of-light limit, and the other [was] on wormholes. It turns out that the two may be connected. The reason we might be able to teleport by exchanging information instantaneously between entangled particles is because they are joined by a microscopic wormhole: a shortcut outside of our space-time. This is still speculation, but it's pretty cool if correct.

If the Big Bang created space-time, and there is no 'before' or 'outside', then how do we come to terms with cosmic expansion? What's it expanding into? *Duncan Waldron*
The universe is not expanding into anything, since there is no 'outside' in this version of cosmology. In fact, even if the universe is infinite, it can still expand. It doesn't need space outside of it to be able to fill since it contains all space anyway. It's just that space is stretching.

Of course, there are now speculative ideas about whether our space-time is all there is, and maybe ours is just a bubble universe in a multiverse of many such bubbles, in which case we are expanding into this multiverse. Similarly, some cosmologists are even daring to consider the question of what came before the Big Bang. Did our universe pop into existence within this already existing multiverse?

These questions are on the boundary between real science (they are extensions of Einstein's ideas) and metaphysics (since we have no way yet of testing them).



Wormholes could be causing quantum teleportation

Our universe could be just one of many, meaning we could be a part of a multiverse

How well do you think the current Big Bang model explains the creation of the universe? Is it possible it could have been an implosion of another universe? *Gareth Jones*
The current Big Bang model does not explain the creation of the universe. It explains what happens once the Big Bang has taken place and not its cause. In fact, our current theories based on general relativity break down at the point of the Big Bang itself – the initial singularity.

We can test some ideas, like the shape of space-time, the amount of matter and energy in our universe and the rate it is expanding, and these can tell us something about how it must have started out. But we have no way of finding out (yet) whether our universe was formed from the collapse of a previous one.

Did time go slower after the Big Bang? *Victoria Wilkinson*
There are all sorts of theories about such fundamental things like the rate of flow of time, the speed of light, the structure of space, but until we have tests that can help us decide which of these is correct, they remain beyond real science. The ideas about time are particularly confusing and counter-intuitive.

On the one hand, we talk about space expanding from the Big Bang and continuing to do so – in fact, even speeding up. Yet on the other hand, we really mean 4D [four dimensional] space-time is expanding.

"Dark matter is frustrating because we have been looking for it for decades now and have come up empty-handed"

But what does this mean about the way the flow of time is changing? I will come clean and admit that this is something that has always baffled me. Maybe there are cosmologists out there who understand what this means. I must remember to get one of them to explain it to me.

Do you think we'll ever discover dark matter and dark energy? *Lee Jenkins*
Of course we will. We're just not there yet. Dark matter is particularly frustrating because we have been looking for it for decades now and have come up empty-handed.

Most astronomers are convinced it's out there, but we don't know what it's made of. We see how it influences matter around it, for example, by holding galaxies together, but it has to be made of a new kind of fundamental particle that we have yet discovered.

Dark energy is more baffling and we know less about it, but we will get there eventually. There is even the (remote) possibility that neither dark matter or dark energy exists. In this case, what we need to do is modify Einstein's theory of gravity to account for this behaviour at large distances, more pull at galactic scales and antigravity at even

Jim has given many public talks; one of which was about determinism at QED in 2011

greater scales to explain the accelerating expansion of the universe.

Just don't mention this to people working in the field of dark matter/energy! They understandably get very upset with the suggestion that they are chasing ghosts.

Is time travel possible? *Tyler Williams*
Depends what you mean. If it's time travel into the future then yes, this is possible, and indeed happens routinely when particles travel close to light speed, because that is when their time slows down. For example, particles called muons, created in the Earth's upper atmosphere, only live a couple of millionths of a second if standing still, but they hurtle down towards the Earth's surface at close to light speed, which slows down their time. You see even at such high speeds, it would still take them longer than their lifetime to reach the surface, and so we would hardly see any arriving, and yet most do get down because they are living their lives in slow motion - despite their speed, if you catch my meaning.

"Time travel into the past is trickier, because it leads to all sorts of paradoxes, but it's not ruled out"

Essentially, they are travelling into the future. If you head off in a rocket at near light speed and come back to Earth a year later, according to your time, you may find that a hundred years have gone by on Earth, because your time was running slower. So, you've travelled 99 years into the future.

Time travel into the past is trickier, because it leads to all sorts of paradoxes, but the fun bit is it's still not ruled out entirely by Einstein's theory of relativity, which is still our best theory on the nature of time.

Artificial Intelligence and robotics have vast potential for future space travel

What effect would artificial intelligence [AI] have on astronomy in the future? *Dolly Brittain*
One of the most obvious effects it will have is that we can send AI space missions out to explore the Solar System and beyond. We already have robots on Mars, for example. AI machines are going to be much more durable than our own fragile bodies in enduring the challenges of space travel.

We are also going to see AI analyse the vast volumes of data we are getting from all our observational astronomy. They can already do this much more quickly than any human and have been doing so since the first electronic calculators were invented. AI will also be much better than us in recognising patterns and picking up subtle properties of the electromagnetic radiation we pick up in our telescopes.

Could you tell us your thoughts on humans having free will and being part of a clockwork universe? *Rachel Goddard*
I give a talk on this very subject and try not to depress the audience too much. While the idea of whether or not we have free will has been tackled by psychologists, neuroscientists and philosophers for a very long time, I think physicists can have some say on the matter based on our understanding of the fundamental laws of the universe.

While the likes of Galileo and Newton described the clockwork Universe as a reductionist, mechanistic reality in which everything is made of fundamental building blocks obeying simple rules that we could, in principle, work out, Einstein then went further. His theory of relativity describes a 4D space-time in which all times coexist. So, it's not just that the future is predetermined - what happens now will decide what happens next - but that it is already 'out there' waiting for us.

While some argue that quantum mechanics brings back an element of indeterminism - things happening by chance and not yet determined exactly - this doesn't really rescue free will.

The best I can say is that we are unable to predict the future reliably, unless we know the state of the entire universe at present to infinite accuracy. Since this is in practice impossible, it's this unpredictability, not whether or not the universe is clockwork, which gives us the 'illusion' of free will.

Much like the 'Astronomical Clock' in Prague, Czech Republic, humans could be living inside a clockwork universe

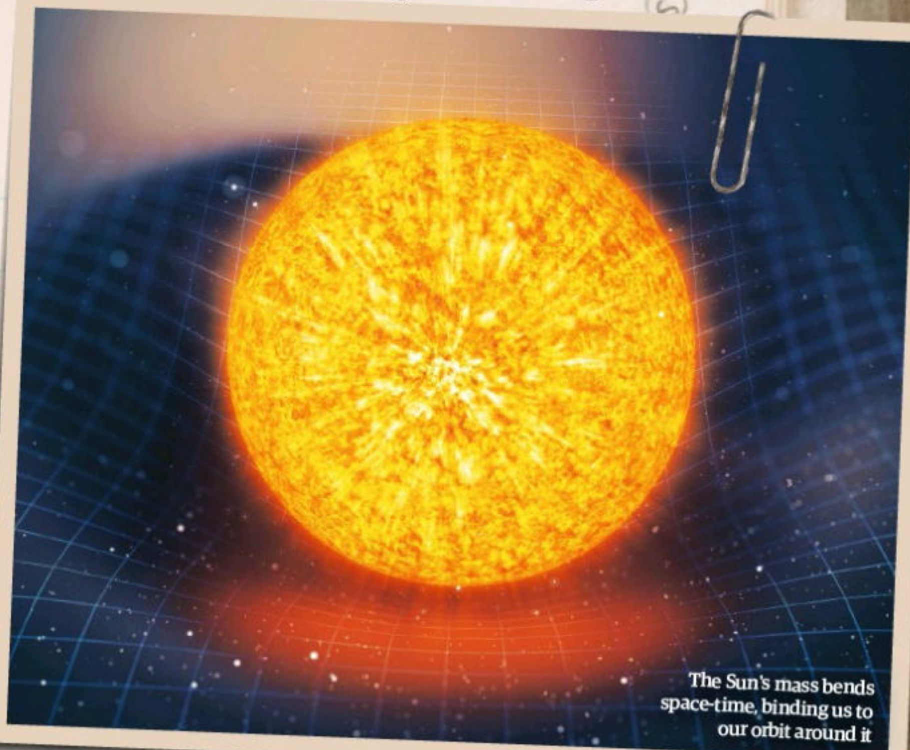
BLUFFER'S GUIDE TO STEPHEN HAWKING'S THESIS

It was the paper that 'broke the Internet'... here's your cheat sheet into the mind of one of the world's greatest physicists

Written by Colin Stuart

Scribbled in pencil on one of its early pages is 'no copying without the author's consent'. In October 2017, Hawking's allowed his PhD thesis - Properties of Expanding Universes - to be made available online through the University of Cambridge's Apollo portal. The website crashed almost immediately under the sheer weight of traffic. It was downloaded almost 60,000 times in the first 24 hours alone.

Hawking was 24 years old when he received his PhD in 1966 and, despite being diagnosed with motor neurone disease at just 21, could still handwrite that "this dissertation is my original work." In a statement to accompany its release, the now 76-year-old physicist said: "By making my PhD thesis Open Access, I hope to inspire people around the world to look up at the stars and not down at their feet; to wonder about our place in the universe and to try and make sense of the cosmos." Here **All About Space** breaks it down, guiding you through the physics until we reach the conclusion that made Hawking a household name.



The Sun's mass bends space-time, binding us to our orbit around it

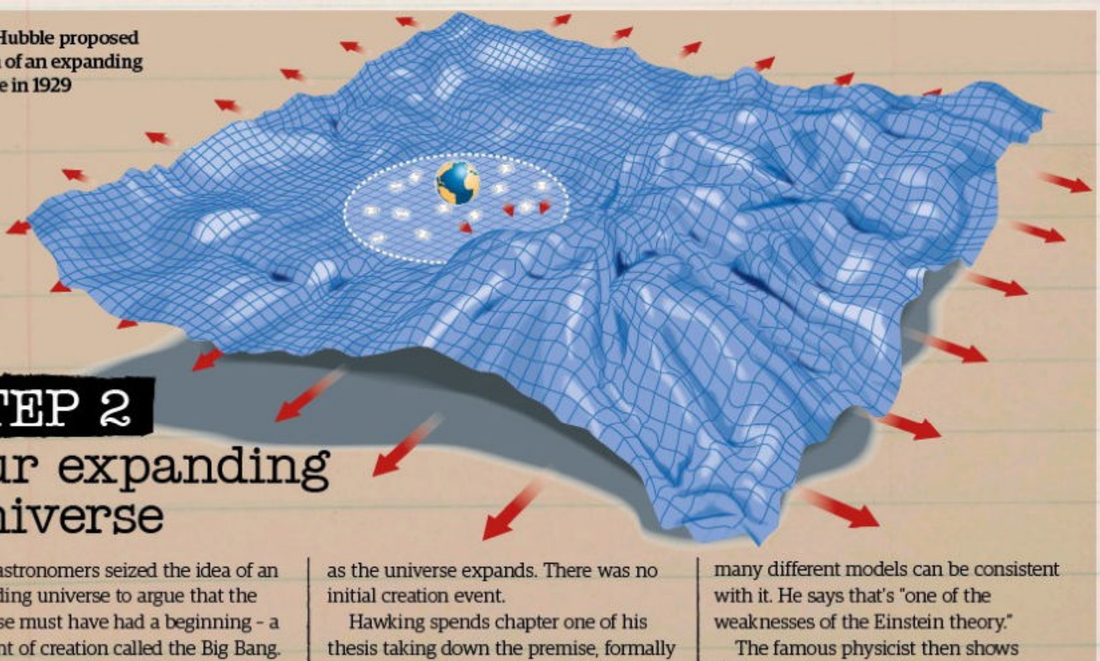
STEP 1
What's it about?

Hawking's PhD thesis relates to Albert Einstein's General Theory of Relativity - the more accurate theory of gravity that replaced Isaac Newton's original ideas. Newton said gravity was a pull between two objects. Einstein said that gravity is the result of massive objects warping the fabric of space and time (space-time) around them. According to Einstein, Earth orbits the Sun because we're caught in the depression our star makes in space-time.

Hawking applies the mathematics of general relativity to models of the birth of our universe (cosmologies). The earliest cosmologies had our universe as a static entity that had existed forever. This idea was so ingrained that when Einstein's original calculations suggested a static universe was unlikely, he added a 'cosmological constant' to the maths in order to keep the universe static. He would later reportedly call it his "greatest blunder."

Things began to change when Edwin Hubble made an important discovery. Hawking writes: "the discovery of the recession of the nebulae [galaxies] by Hubble led to the abandonment of static models in favour of ones in which we're expanding."

"Hawking applies the mathematics of general relativity to models of the birth of our universe"



Edwin Hubble proposed the idea of an expanding universe in 1929

STEP 2
Our expanding universe

Some astronomers seized the idea of an expanding universe to argue that the universe must have had a beginning - a moment of creation called the Big Bang. The name was coined by Fred Hoyle, an advocate of the alternative Steady State Model. This theory states that the universe has been around forever and that new stars form in the gaps created as the universe expands. There was no initial creation event.

Hawking spends chapter one of his thesis taking down the premise, formally encapsulated in a model called Hoyle-Narlikar theory. Hawking laments that although the General Theory of Relativity is powerful, it allows for many different solutions to its equations. That means many different models can be consistent with it. He says that's "one of the weaknesses of the Einstein theory."

The famous physicist then shows that a requirement of Hoyle-Narlikar theory appears to "exclude those models that seem to correspond to the actual universe." In short, the Steady State Model fails to match observation.

Matter is thought to be evenly distributed throughout the universe

STEP 3
Space: it looks the same everywhere

Hawking says that the assumptions of the Hoyle-Narlikar theory are in direct contradiction of the Robertson-Walker metric, named after American physicist Howard P. Robertson and British mathematician Arthur Walker. Today it is more widely called the Friedmann-Lemaître-Robertson-Walker (FLRW) metric. A metric is an exact solution to the equations of Einstein's General Theory of Relativity. Devised in the 1920s and 1930s, FLRW forms the basis of our modern model of the universe. Its key feature is that it assumes matter is evenly distributed in an expanding (or contracting) universe - a premise backed up by astronomical observations.

Interestingly, Hawking offers Hoyle and Narlikar a ray of hope. "A possible way to save the Hoyle-Narlikar theory would be to allow masses of both positive and negative sign," he writes, before adding: "there does not seem to be any matter having these properties in our region of space." Today we know that the expansion of the universe is accelerating, perhaps due to dark energy - a shadowy entity with an anti-gravitational property perhaps akin to particles with a negative mass.

Uniform cloud
With top-down formation, a relatively uniform cloud of material would slowly start to contract.

First star formation
As the density of material increases, the first stars would start to form in smaller collapses in the cloud.

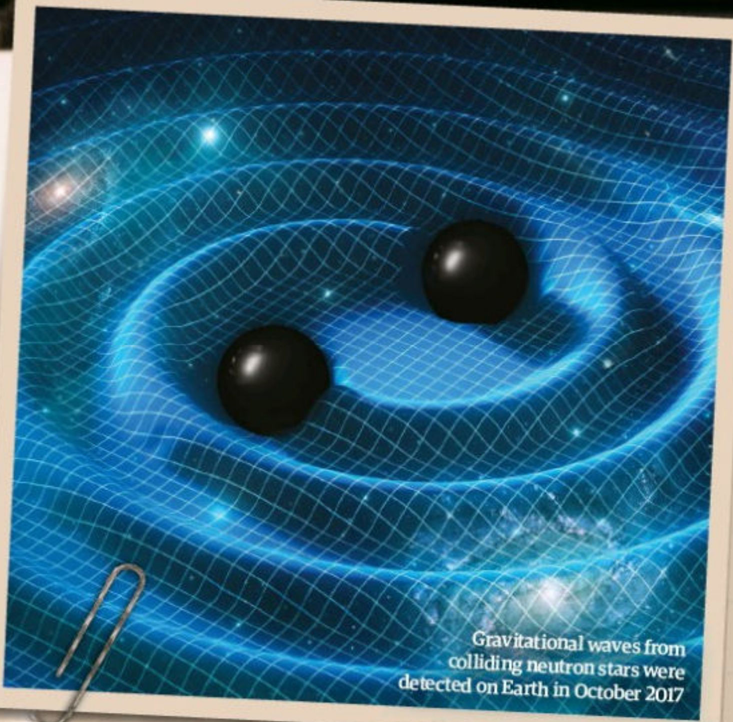
Spin
As the cloud contracts, it will begin to spin as random collisions end up favouring one direction or another.

STEP 4
The problem with galaxies

Even geniuses get it wrong sometimes. Hawking's second chapter covers perturbations - small variations in the local curvature of space-time - and how they evolve as the universe expands. He says that a small perturbation "will not contract to form a galaxy." Later in the chapter he goes on to say: "we see that galaxies cannot form as the result of the growth of small perturbations."

That couldn't be further from our modern-day picture of how galaxies form. The key ingredient Hawking was missing is dark matter, an invisible substance thought to be spread throughout the universe which provides a gravitational glue that holds galaxies together. Dark matter gathered around small space-time perturbations, eventually drawing in more and more material until early galaxies formed.

Our modern working cosmological picture is known as the CDM model (pronounced Lambda CDM). Lambda is the Greek letter cosmologists use to denote the cosmological constant that Einstein originally introduced (albeit for the wrong reasons). CDM stands for cold dark matter. These two factors have been added to the FLRW model since Hawking wrote his thesis.



Gravitational waves from colliding neutron stars were detected on Earth in October 2017

"Hawking uses Einstein's equations to show that gravitational waves aren't absorbed by matter in the universe as they travel through"

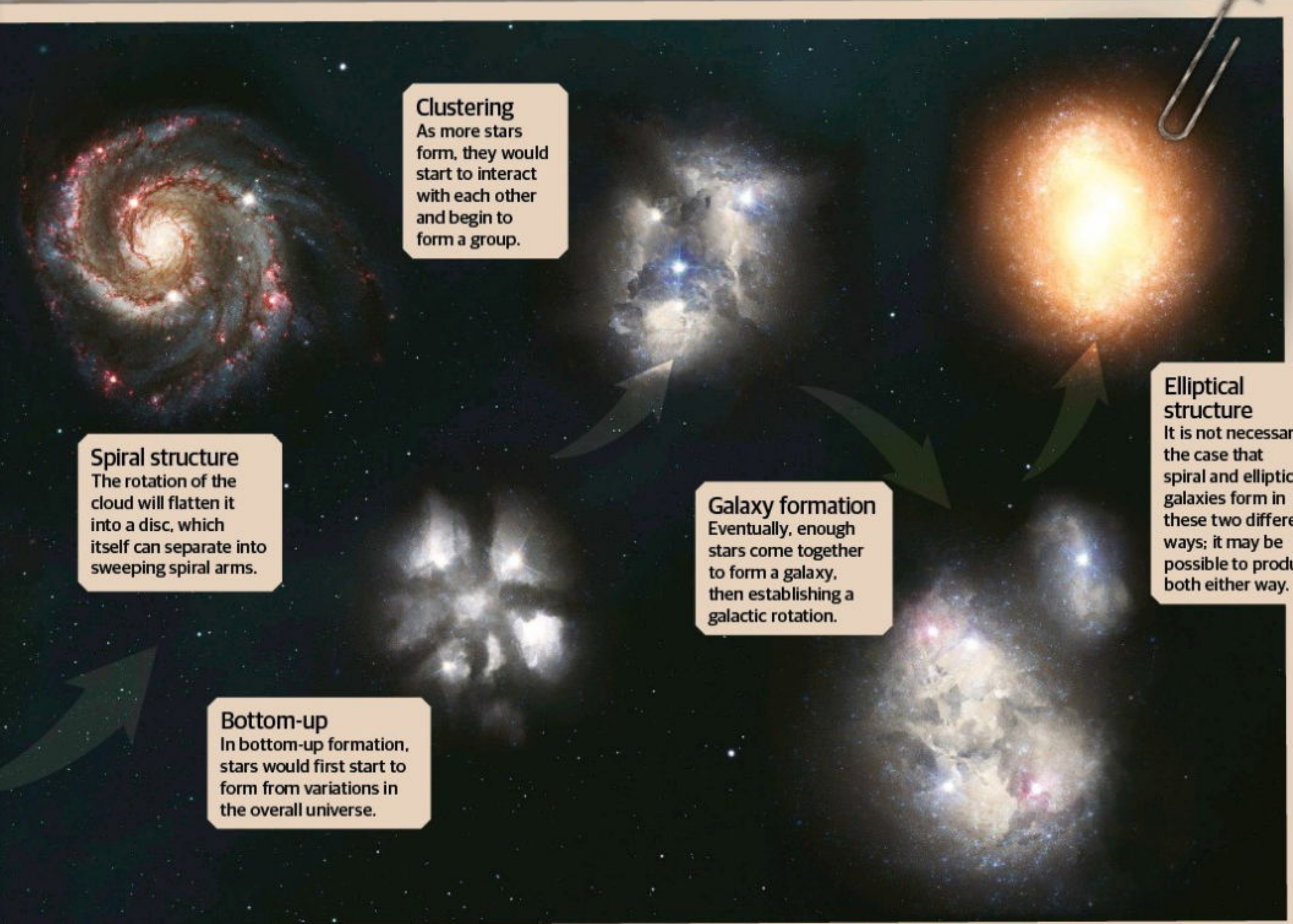
STEP 5

Gravitational waves don't disappear

Where Hawking was wrong on galaxies, he was very right on gravitational waves - ripples in the fabric of space-time that move outwards through the universe. They were predicted by Einstein when he first devised his Theory of General Relativity back in 1915, and in Hawking's time were also known as gravitational radiation.

Hawking uses Einstein's equations to show that gravitational waves aren't absorbed by matter in the universe as they travel through it, assuming the universe is largely made of dust. In fact, Hawking says that "gravitational radiation behaves in much the same way as other radiation fields [such as light]." The physicist does note how esoteric the topic is in the 1960s. "This is slightly academic since gravitational radiation has not yet been detected, let alone investigated."

It would take physicists until September 2015 to detect gravitational waves for the first time using the Laser Interferometer Gravitational-Wave Observatory (LIGO). They were produced by the collision of two black holes - one 36- and the other 29-times the mass of the Sun - about 1.3-billion-light-years away.



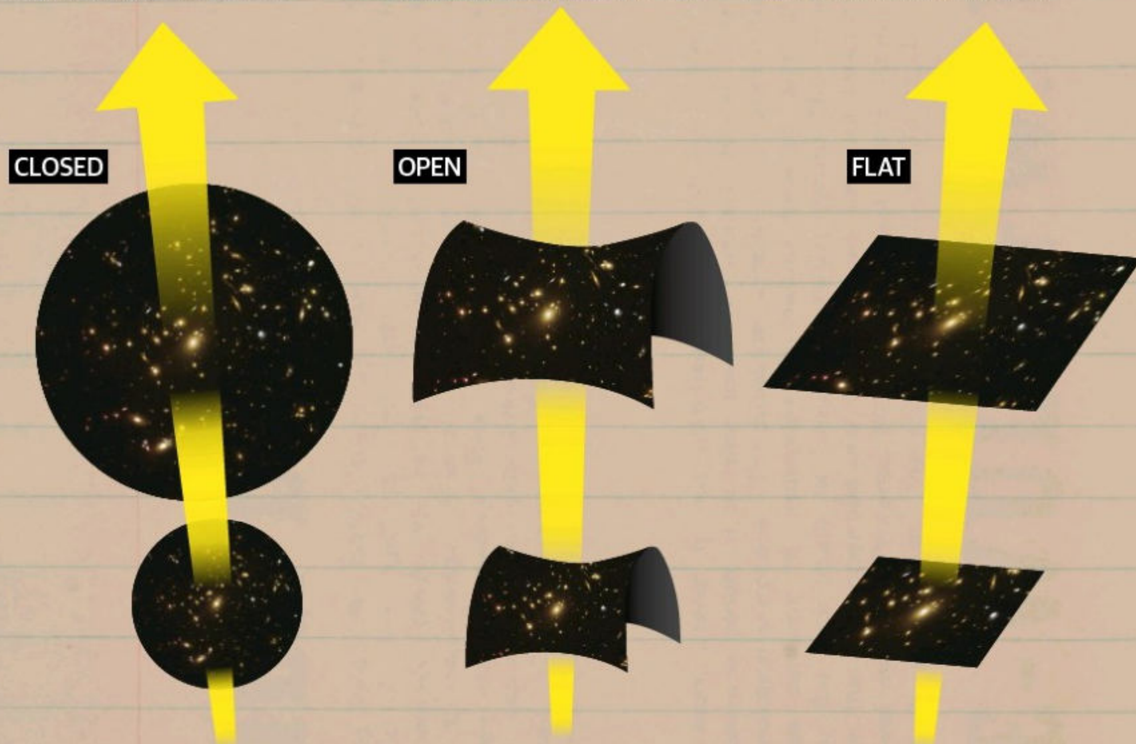
STEP 6

Are we living in an open, closed or flat cosmos?

Hawking is heading for a groundbreaking conclusion, but first he sets himself up by introducing the idea of the overall shape of space. There are three general forms the curvature of space can take: open, closed or flat.

A closed universe resembles Earth's surface - it has no boundary. You can keep travelling around the planet without coming to an edge. An open universe is shaped more like a saddle. A flat universe, as the name suggests, is like a sheet of paper.

Imagine a triangle drawn onto the surface. We all learn at school that the angles inside a triangle sum to 180 degrees. However, that's only the case for triangles on flat surfaces, not open or closed ones. Draw a line from the Earth's North Pole down to the equator, before taking a 90-degree turn to travel along it. Then make another 90-degree turn back towards the North Pole. The angle between your path away from and towards the North Pole cannot be zero, so the angles inside that triangle must add up to more than 180 degrees.




The spiral of our own Milky Way can be seen on a clear night

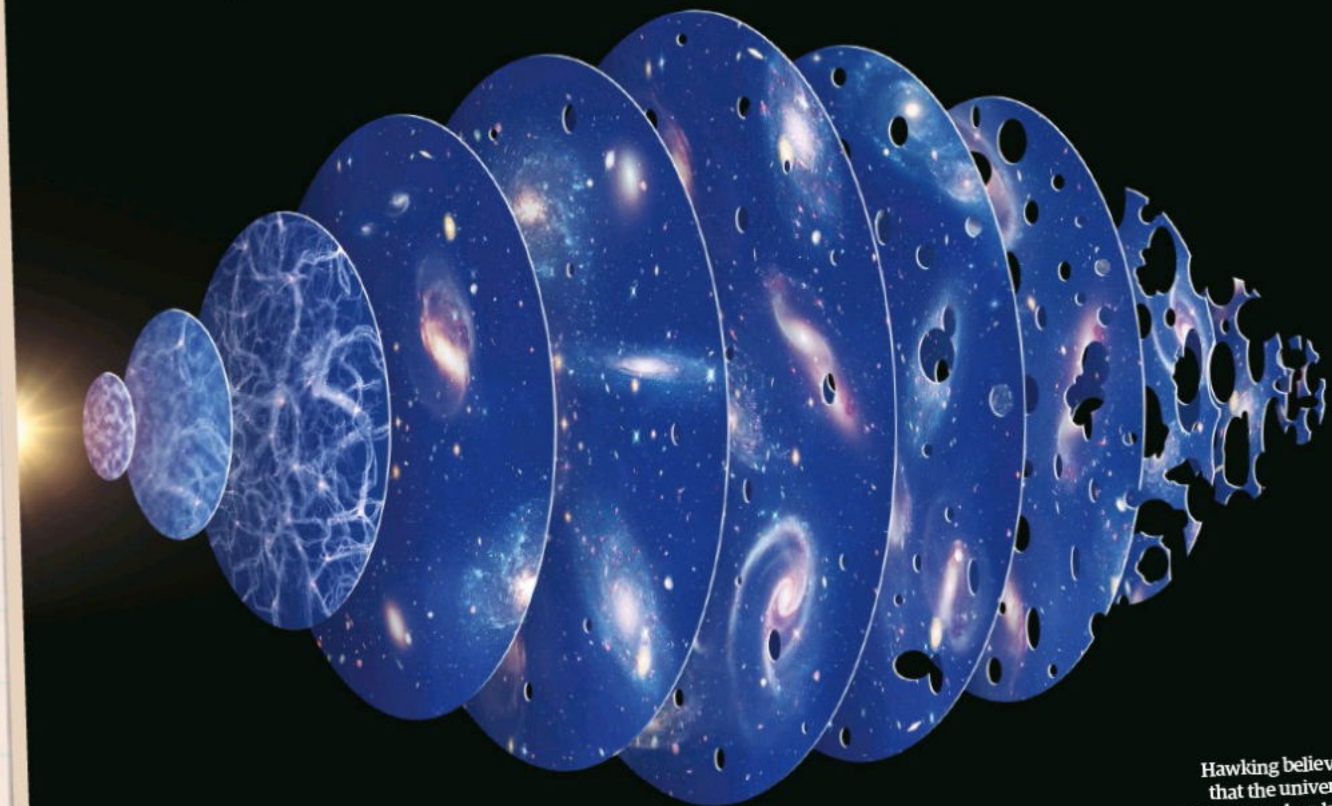
STEP 7

The universe is flat!

Hawking then links the idea of open and closed universes to Cauchy surfaces, named after the French mathematician and physicist Augustin-Louis Cauchy (1789 - 1857). A Cauchy surface is a slice through space-time, the equivalent of an instant of time. All points on the surface are connected in time. A path along a Cauchy surface cannot see you revisit a previous moment. In Hawking's own words: "A Cauchy surface will be taken to mean a complete, connected space-like surface that intersects every time-like and null line once and once only."

He then says that closed universes are known as "compact" Cauchy surfaces and open universes as "non-compact" ones. The former example is said to have "positive" curvature, the latter "negative" curvature. A flat universe has zero curvature. He moves on to set up the landmark assertions he's about to make about singularities by saying they are "applicable to models... with surfaces... which have negative or zero curvature." Modern astronomers believe the universe is flat, meaning its zero curvature satisfies Hawking's conditions.

> "Hawking says that space-time can begin and end at a singularity, and what's more he can prove it"



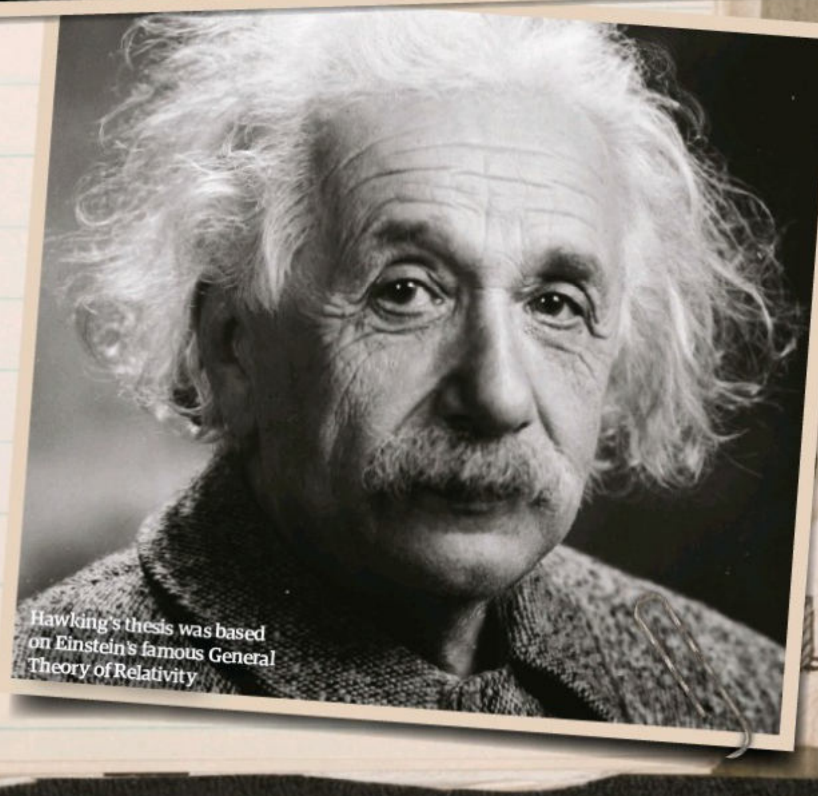
Hawking believes that the universe begins and ends at a single point

STEP 8

Hawking drops a bombshell

Most of the early chapters of Hawking's thesis are unremarkable - they don't offer anything particularly revolutionary, and he even get things a few things wrong. However, in his final chapter the physicist drops a bombshell that will make his name and ignite a stellar career, during which he will become one of the most famous scientist on the planet.

He says that space-time can begin and end at a singularity, and what's more he can prove it. A singularity is an infinitely small and infinitely dense point. It literally has zero size, and space and time both end (or begin) at a singularity. They had been predicted for decades, particularly when physicists started to apply Einstein's General Theory of Relativity to the picture of an expanding universe. If the universe is expanding today then it was smaller yesterday. Keep working back and you find all matter in the universe condensed into a tiny, hot point - the moment of creation, a Big Bang. But just how do you prove that you can indeed get singularities in space-time?



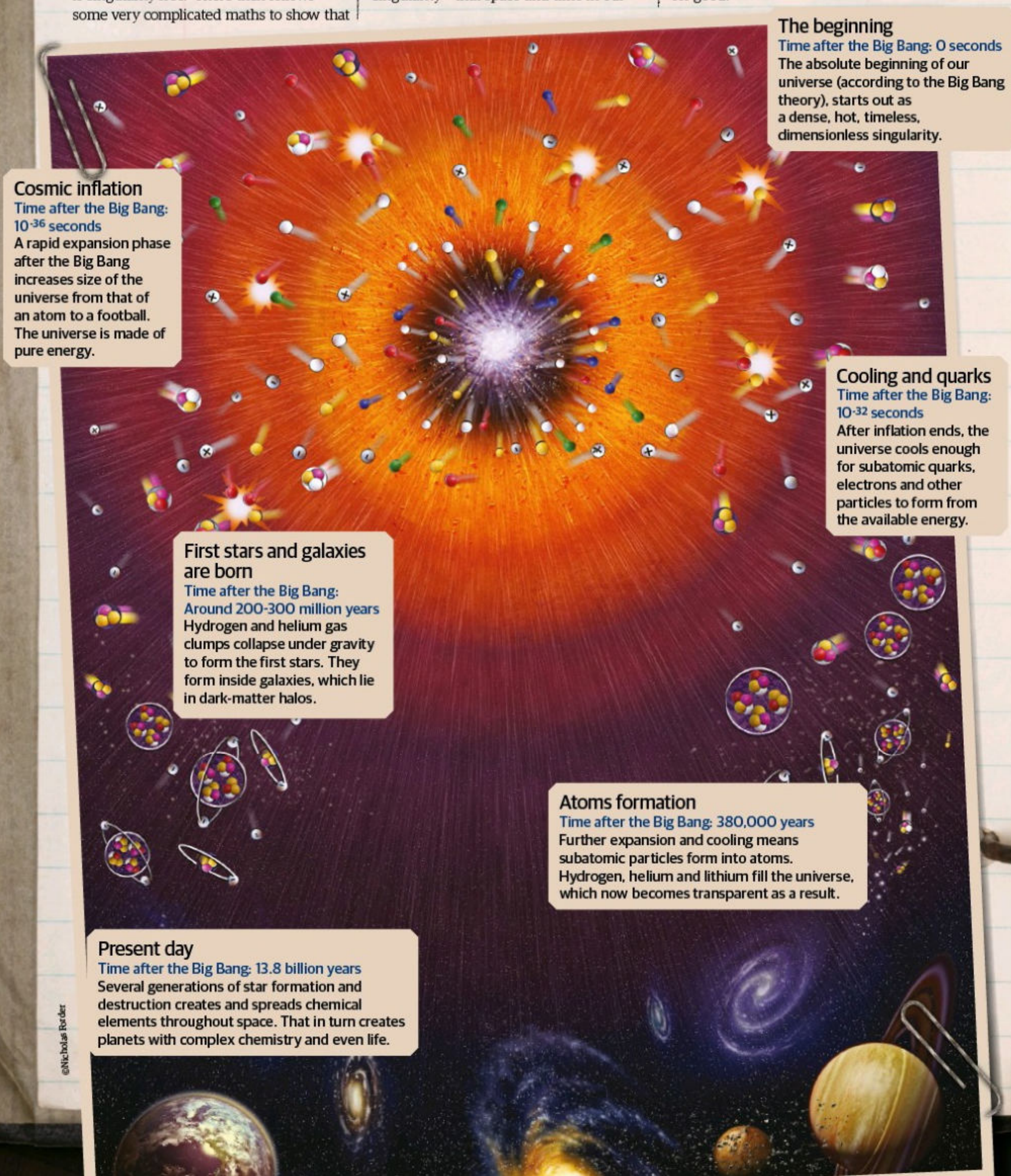
Hawking's thesis was based on Einstein's famous General Theory of Relativity

STEP 9

Hawking's proof that the Big Bang happened

Hawking's proof leans on a very old method for proving a mathematical theory: proof by contradiction. First you assume the thing you are trying to prove isn't true, then show that the resulting conclusions are demonstrably false. In fact, Hawking's most important section begins with the words "assume that space-time is singularity-free." There then follows some very complicated maths to show that such a universe would be simultaneously both open and closed - compact and non-compact at the same time. "This is a contradiction," Hawking says. "Thus the assumption that space-time is non-singular must be false."

In one swoop Hawking had proven that it is possible for space-time to begin as a singularity - that space and time in our universe could have had a origin. The Big Bang theory had just received a significant shot in the arm. Hawking started to write his PhD in October 1965, just 17 months after the discovery of the Cosmic Microwave Background - the leftover energy from the Big Bang. Together these discoveries buried the Steady State Model for good.



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BREWING BEER IN SPACE

WRITTEN BY LEE CAVENDISH

© NASA

With Budweiser's intention to make itself the beer of Mars, **All About Space** digs a little deeper into its beneficial implications

The formidable task of putting humans on the surface of Mars seems to be very newsworthy at the moment, especially with the surging efforts of SpaceX, Virgin Galactic and NASA. These organisations have a long-withstanding desire to, once again, go where no man has gone before. But with all these efforts being made in an attempt to travel to Mars, another organisation has already started to plan for the momentous occasion. Last year, the international lager distributor Budweiser announced its aim to make its 142-year-old product the 'beer of Mars.'

"With this bold, new dream Budweiser is celebrating the entrepreneurial spirit in which our iconic brand was founded upon. Through our relentless focus on quality and innovation, Budweiser can today be enjoyed in every corner of the world, but we now believe it is time for the 'King of Beers' to set its sights on its next destination," says Ricardo Marques, vice president of marketing at Budweiser. "When the dream of colonising Mars becomes a reality, Budweiser will be there to toast the next great step for mankind."

Much like every other great ambition in the world, results will not be achieved without significant challenges. It is one thing to put humans on Mars and colonise the harsh, dry planet, but brewing an alcoholic beverage that has been around for nearly a century-and-a-half brings a unique set of obstacles. Although some people say it isn't necessary to have beer in space or on a different planet, it still provides an intriguing task that could have enduring effects on space agriculture and water extraction in extraterrestrial environments.

On 21 November 2017, Anheuser-Busch, the parent company of Budweiser, announced they were taking the first steps in upholding their commitment of being the first beer on Mars. This announcement outlined its plan to conduct two experiments on the most unique laboratory humans have ever created, the International Space Station (ISS). Budweiser partnered up with the Center for Advancement of Science in Space (CASIS), a non-profit organisation that manages the United States National Laboratory on the ISS. With the research facility available for use, Anheuser-Busch then had to prepare the two experiments to be sent, which led to an additional collaboration with Space Tango.

Space Tango is a payload development company that created its own CubeLab modules and which will house the two individual experiments. These include a handful of barley seeds in each cube, as barley is a key ingredient in the production

of the world's most popular lagers. On 15 December 2017, SpaceX launched its 13th resupply mission to the ISS, shooting a Dragon capsule with about 2,177 kilograms (4,800 pounds) of research equipment, including these ever-so precious barley experiments into space.

In one cube, the barley seeds will be left in storage to see what happens when they're exposed to a microgravity environment for a month. In the other cube, the seeds will be fed and watered over the same period to see how they grow in the same research facility, also known as seed germination. On Earth, barley will grow between six and ten inches (15 to 25 centimetres) in two weeks, but who knows what length it could grow to without the constraints of gravity restricting its development.

With the journey to the Red Planet taking roughly seven months, the effects of microgravity as they are hurtling through space could cause major damage to the ingredients. This is not only upsetting – as you can no longer have a cool refreshing alcoholic drink on a different planet – but it is also highly inefficient, as worthless baggage means wasted spacecraft fuel. This is why initial investigations have begun with two short-term experiments on board the relatively nearby ISS laboratory. These experiments will also play a large role in understanding how to brew the Bud once humans have colonised Mars. Mars has a diameter of 6,779 kilometres (4,212 miles), which is 53 per cent the size of Earth, and is about ten-times less massive than our home planet. This leads to a much weaker surface gravity on Mars, where it is only 38 per cent of Earth's. This would mean you'd weigh roughly a third of your Earth weight on Mars. Although our Martian probes have done a fantastic job exploring the surface, they cannot tell us what it would be like starting a farm, so to see what effect low gravity has on plant germination is vital in this research.

There have been many agricultural experiments completed on board the ISS. Throughout the years, the floating home has grown many plants and vegetables as it provides many advantages for a manned spaceflight mission. The art of growing vegetables in space would mean that the crew could minimise the amount of room taken up on the spacecraft, making it more sustainable. Not only that, but it can have a huge psychological benefit to the astronauts, providing them with an activity that gives them a sense of comfort and relaxation. When you're on a long-term spaceflight, for example a seven-month flight to Mars, these benefits can prove vital.

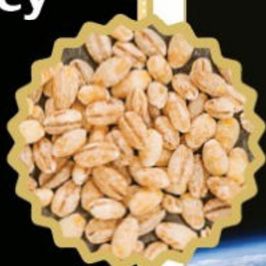
Dr Gary Hanning, the director of Global Barley Research for Anheuser-Busch, explained to **All About Space** that this research presents a rare opportunity to study barley in a way that can improve its quality on Earth, as well as off it: "As Budweiser works towards its goal of being the first beer on Mars, taking the first steps with barley experimentation on the Space Station [ISS] allows us to investigate various key traits, like germination, in an even more extreme environment," says Hanning. "[This is] information that is pertinent to our goals of developing high-quality malting barley here on Earth, and Budweiser on Mars."

There are complications though, as plants require a specific environment that is best suited for Earth, and not the harsh territories beyond. This list includes space (both height and between plants), nutrients for plant growth, water, a specific temperature and the appropriate light intensity. "All these present unique challenges on Mars. Those same factors are critical for barley growth on Earth," Hanning continues. "For malting, the key parameters are water, temperature and air flow. How to have those available will be important for any industry in space."

It is key to realise that the motivation to make Budweiser the go-to alcoholic drink that is on average about 225-million-kilometres (140-million-miles) away will have long-standing effects on extraterrestrial habitation, and not just for growing

> "When the dream of colonising Mars becomes a reality, Budweiser will be there to toast the next great step for mankind"

Initial barley testing



In order to test the feasibility of brewing beer in space and on Mars, two barley experiments were recently sent to the International Space Station

Seed exposure

In one of the CubeLab modules, the barley seeds will simply be kept in storage to see how they react to the microgravity environment. In an ideal situation, barley seeds are best kept in a cool and dry place, but space can lead to the exposure of cosmic rays, among other forms of unprotected radiation. This experiment will see if storage in space is possible.

Seed germination

Unlike the seed exposure experiment, these barley seeds will be watered and fed in a similar fashion to those down on Earth. On Earth, barley seeds will typically grow between six and ten inches (15 to 25 centimetres) tall, but on board the ISS the rate of growth could be extremely different.

SpaceX's Dragon capsule carrying the barley experiments returned to Earth on 13 January 2018

Why beer ingredients are important for space travel

The five constituent ingredients of Budweiser are the key to growing and storing crops while travelling in space and extracting clean water on Mars

Water

1 About 90 per cent of Budwesier is water, making it the most major element of the refreshing lager. However, when you go beyond Earth it becomes a limited and sacred resource. If humans were to colonise Mars, retracting water from beneath its surface and desalinating it would become the top priority.

Barley

2 Not only is barley used in the production of beer, it is also used in the production of many foods that are beneficial for a human's health. The results from these barley experiments could prove to be highly influential on an astronaut's diet.

Hops

3 These flowers, like any other flowers, need sunlight, water, nutrients and room to grow. These necessities have shown to give astronauts a sense of calmness and relaxation in caring for them.

Rice

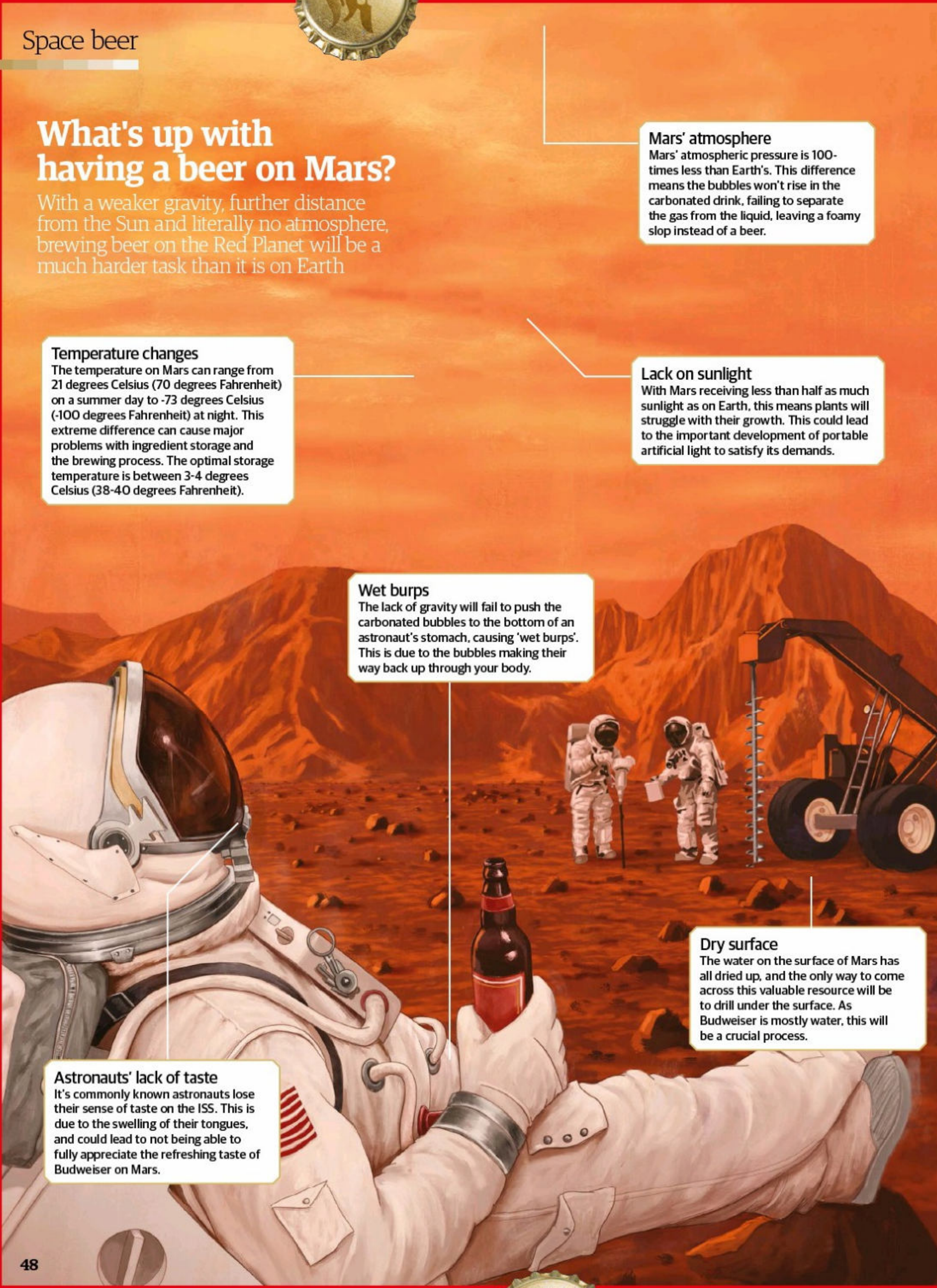
4 Rice is used in many dishes across the world; this is because it is a good source of carbohydrates in your diet. Carbohydrates are important in giving a person the energy to complete their everyday tasks, which can be the difference between life and death in space.

Yeast

5 Yeast and humans are about 70 per cent similar in genetics, this makes them the most ideal microbes to examine in order to see how human cells would react to wandering through space. The results have shown that space can be damaging to yeast cells, which doesn't look good for human cells.

What's up with having a beer on Mars?

With a weaker gravity, further distance from the Sun and literally no atmosphere, brewing beer on the Red Planet will be a much harder task than it is on Earth



Mars' atmosphere
Mars' atmospheric pressure is 100-times less than Earth's. This difference means the bubbles won't rise in the carbonated drink, failing to separate the gas from the liquid, leaving a foamy slop instead of a beer.

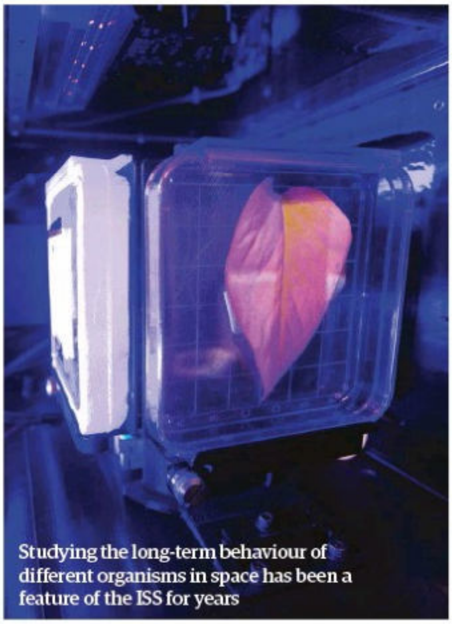
Temperature changes
The temperature on Mars can range from 21 degrees Celsius (70 degrees Fahrenheit) on a summer day to -73 degrees Celsius (-100 degrees Fahrenheit) at night. This extreme difference can cause major problems with ingredient storage and the brewing process. The optimal storage temperature is between 3-4 degrees Celsius (38-40 degrees Fahrenheit).

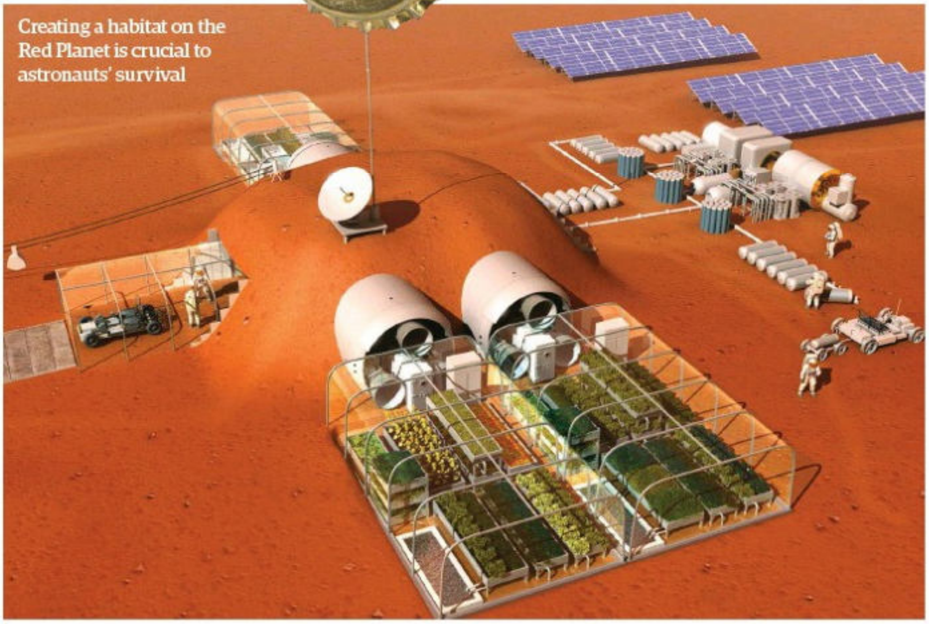
Lack on sunlight
With Mars receiving less than half as much sunlight as on Earth, this means plants will struggle with their growth. This could lead to the important development of portable artificial light to satisfy its demands.

Wet burps
The lack of gravity will fail to push the carbonated bubbles to the bottom of an astronaut's stomach, causing 'wet burps'. This is due to the bubbles making their way back up through your body.

Dry surface
The water on the surface of Mars has all dried up, and the only way to come across this valuable resource will be to drill under the surface. As Budweiser is mostly water, this will be a crucial process.

Astronauts' lack of taste
It's commonly known astronauts lose their sense of taste on the ISS. This is due to the swelling of their tongues, and could lead to not being able to fully appreciate the refreshing taste of Budweiser on Mars.


Studying the long-term behaviour of different organisms in space has been a feature of the ISS for years


Creating a habitat on the Red Planet is crucial to astronauts' survival

food. Officials at Budweiser have outlined that they hope to tackle the issue of extracting and desalinating the water on Mars.

NASA's Mars Reconnaissance Orbiter has recently discovered eight sites of buried water ice locked away over nine metres below some steep slopes. This water could provide future explorers with an essential liquid, needed for the human race to survive on Mars. Unfortunately, Mars' inhospitable surface conditions, mean water will not exist as a liquid - as surface oceans, lakes or even puddles. As 90 per cent of Budweiser is water, it's essential to have fresh water in order to manufacture the refreshing, crisp taste in an alien environment.

Tapping into the water extracts hidden away on the Red Planet is one thing, but desalinating it and making it safe for human consumption is another. Particularly when it comes to perchlorates, which are harmful and toxic chemicals that has been proven to reside in Martian soil. Although there are processes used on Earth to desalinate water, such as swapping out the salt molecules - known as ion exchange - and pushing water through a tiny membrane to leave the harmful molecules behind - also known as reverse osmosis - there is an issue with bringing these processes to Mars. The issue with these processes is that the equipment is very fragile, and if just one piece breaks, it would take at least another six months to get a replacement out there. Nonetheless, it is still feasible.

When it comes to examining how microgravity changes different types of vegetation, yeast has already been the subject of many experiments on the ISS. Due to humans and yeast sharing 70 per cent of the same genetics, yeast has become the closest match for testing the effects of space on human cells. The results from this study showed that spaceflight could have damaging effects on the cellular processes in yeast, which could also prove harmful for our astronauts' wellbeing.

"Plants require a specific environment that is best suited for Earth, and not the harsh territories beyond"

This degree of exposure in a harsh environment can also damage another important ingredient of Budweiser, rice. In August 2011, 100 grains of brown rice were sent to the ISS with the intention of measuring its germination rate and the affects of storage on the crop. The metal container holding the test subject was kept outside the laboratory, where it witnessed the harsh environment of space. The results showed that when half the rice was removed after 13 months, and the other half in 20 months, the rate of germination had decreased more than 48 per cent when compared to the samples taken on Earth. This proves that space travel will have a damaging effect on the rice, which will consequently have a negative effect on the beer brewing process.


The International Space Station is the best laboratory for testing how microgravity changes a subject

Hops give beer its bitter flavour, which is the gem of Budweiser's taste. To grow hops, much sunlight is needed in order to blossom. This is a problem on Mars; as the Red Planet is much further away from the Sun than Earth, it only receives less than half as much sunlight. Artificial light will become a necessity because of this predicament, and the development of artificial light will benefit many plants and crops while colonisation settles down.

The work that has already been done, and what we already know about the brewing process, has shown there are inherent problems to overcome. With all that being said, the work that is being done both here on Earth and in the ISS laboratory will provide long-lasting, important and beneficial improvements on how we counteract agricultural and water-based problems for space travel.

On the 13 January 2018, the ISS released the SpaceX Dragon cargo containing the experiments, where it splash-landed in the Pacific Ocean at 3:36pm Greenwich Mean Time (10:36am Eastern Time). "The samples are expected back in Fort Collins [Colorado, United States] later this week. Then, we will begin the genetic analysis and interpret those results. We are already in discussion with SpaceTango on the next experiments," explains Hanning, only two days after the Dragon capsule's splashdown.

When asked about what the next step is for making Budweiser the beer of Mars, Hanning replied: "We are focused on barley production. A part of that is linking with other plant scientists working in space on various aspects identified as limiting for agricultural production.

"There are many projects by other scientists focused on fluid dynamics that will benefit AB [Anheuser-Busch] when the time comes to move the micro-gravity brewing aspect ahead."

So while we wait on the preliminary results to come back concerning the barley experiments, all we can do is just sit back, close our eyes and dream about the day we can crack open a cold one on the neighbouring Red Planet, Mars.

RETURN TO COMET

NASA is one step closer to revisiting Rosetta's comet and bringing a piece of it back home

Written by Natalie Starkey

NASA have some speculative yet fascinating plans to return to comet 67P/Churyumov-Gerasimenko (hereafter 67P), first visited by the ESA's Rosetta spacecraft in 2014. The potential new comet mission called CAESAR - Comet Astrobiology Exploration SAmple Return - would become the first spacecraft to collect samples from the surface of a comet and return them to Earth.

"If CAESAR is ultimately selected to fly, this is absolutely tremendous news! There are still many unanswered questions about 67P," says Professor Ian Wright from The Open University and principal investigator of Ptolemy on Rosetta's Philae lander.

67P

© Adrian Mann

What Rosetta told us about Comet 67P

The world was found to be very different to what scientists were expecting

A comet's aroma
It's lucky the Rosetta team sent a robot to investigate the comet and not humans, as Rosetta found out exactly how comet 67P smells, and it's not very nice. Scientists discovered that the comet emits a stench which smells like a mix of cat urine, bitter almonds and rotten eggs.

A tough nut to crack
When Rosetta's Philae landed on the comet, it quickly showed scientists that this 'dirty snowball' was a lot tougher, and harder, than they were expecting. Comets are generally thought of as fluffy and delicate, but the Philae lander measured 67P's surface to be impenetrably hard on the first touchdown. This unexpected surface quality is one of the reasons Philae made its famous hop, skip and bounce across the cometary landscape.

Detection of amino acids
Dr Bonnie Buratti, the NASA Rosetta project scientist, explains that her most exciting scientific result to arise from Rosetta was the discovery of abundant organic molecules, including the amino acid glycine. "Although glycine was brought back by NASA's Stardust, there was always the question of contamination. Scientists believe comets, which formed in the Kuiper Belt but wander into the inner Solar System, impacted the early Earth to deliver complex organic (pre-biotic) molecules, which in turn became the building blocks of life."

The comet's terrain
67P's surface hosts cliffs that are hard to miss thanks to their 1km height on an object measuring just four kilometres in diameter. Comet 67P's low-gravity environment means that if a person were to leap off the top of one of these cliffs, they'd be able to land safely on the ground below. They'd float down like a feather instead of falling like a lead balloon.

Origins of water on Earth
One of the most exciting parts of the Rosetta mission was finding out about the comet's water, stoking the debate about the origins of water on Earth. 67P's water does not match Earth's particular flavour, suggesting that it, and comets like it, were not responsible for delivering our precious drinking solvent. However, it's not to say that other comets or asteroids are not responsible instead.

67P's reptilian behaviour
Rosetta discovered that comets exfoliate themselves as they orbit the Sun. The comet produces twice as much dust when travelling between 2.7 and 2.5AU from the Sun, shedding its material – accumulated from its travels in the outer Solar System – from its surface into space. This exposure explains how a comet sheds its outer dust shell – like peeling a layer from an onion – a feature that was not well known. 67P is thought to lose up to a metre from its surface every orbit.

Cometary seasons affect activity
While it's long been known that comets experience seasonal variations across their surface, what Rosetta discovered was that these changes drive cometary activity. 67P's northern lobe experiences very long summers and its southern lobe the opposite; very long, dark, cold winters. This is until the comet reaches perihelion – its closest point to the Sun – when the southern hemisphere is suddenly heated, driving a new type of activity: the movement of up to one metre-sized boulders across its surface.

In December 2017, CAESAR was selected as one of two mission proposals to receive additional funding from NASA. The other is Dragonfly, which has the lofty aims of visiting and landing on Titan, Saturn's largest moon. CAESAR and Dragonfly will now go head-to-head in a fierce battle, but only one of them will reach its goal of becoming a fully fledged spacecraft, winning the coveted spot as NASA's fourth New Frontiers mission. In spring 2019, NASA will select one mission to continue with development phases, but whether it is CAESAR or Dragonfly that receives the $850 million, the spacecraft must be delivered for a launch by 2025.

Dr Steve Squyres, principal investigator of the CAESAR mission proposal says: "All the decisions we've made are aimed at maximising the scientific value of the sample within the budget, schedule, and risk constraints of the New Frontiers program."

You will have heard of the previous New Frontiers missions; the famous New Horizons, which visited Pluto in 2015, and Juno, which visited Jupiter in 2016. In September 2016, OSIRIS-REx became the third New Frontiers mission to launch. It is now making its way towards asteroid Bennu to collect a sample of its surface later this year and return a sample to Earth in 2023.

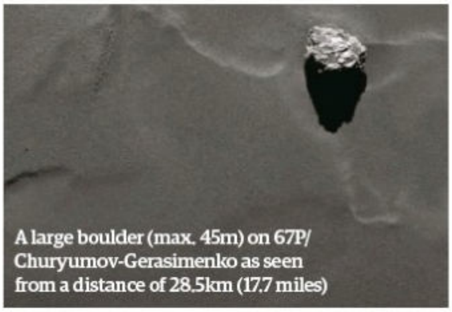
Interestingly, CAESAR and Dragonfly both intend to visit Solar System objects that have been investigated before. Dragonfly will follow in the footsteps of the Cassini-Huygens mission that studied Titan's atmosphere and deployed the Huygens probe to its surface. CAESAR's 67P target has been studied in immense detail in recent years by Rosetta. However, in neither case does this make their target any less important.

To truly understand the space objects such as planets, comets and asteroids that share our little corner of the galaxy, we must study them up close and personal. While telescope studies are often a first, and extremely useful, step in space exploration, scientists tend to learn the most about a far-away world when it is visited by a spacecraft. Being able to clearly see its surface, how it behaves over a period of time and potentially even analyse its rocks and atmosphere is vital.

Comets are especially valuable in this endeavour. Dr Bonnie Buratti, planetary astronomer at NASA's JPL and ESA Rosetta project scientist explains: "Comets are debris left over from the early stages of the formation of the Solar System – fragments of dust and gas that never formed into planets. Studying this primitive material will enable us to peer back in time to the very earliest phases of the planets' formation."

Because of this, comets hold a wealth of information about the ingredients required to make a Solar System, and the conditions that existed in the earliest days of its formation around 4.6 billion years ago. Some of these ingredients are the incredibly important organic building blocks of life. If we want to understand how life arrived on Earth and managed to get such a foothold on our precious planet, then we must study comets.

It might seem strange that CAESAR's target is not a new comet that has not been studied before. After all, there are many millions, possibly billions, of other comets in the Solar System that could be called on instead of going back to 67P. There are, however, many major advantages in revisiting a space object: scientists can build on the wealth of information already gained from the previous mission.



A large boulder (max. 45m) on 67P/Churyumov-Gerasimenko as seen from a distance of 28.5km (17.7 miles)

Wright explains: "It makes so much good sense to target 67P. It's a known object. While another comet might have a different story to tell, and therefore extend our knowledge further, it might also come with a whole lot of unknown technical challenges."

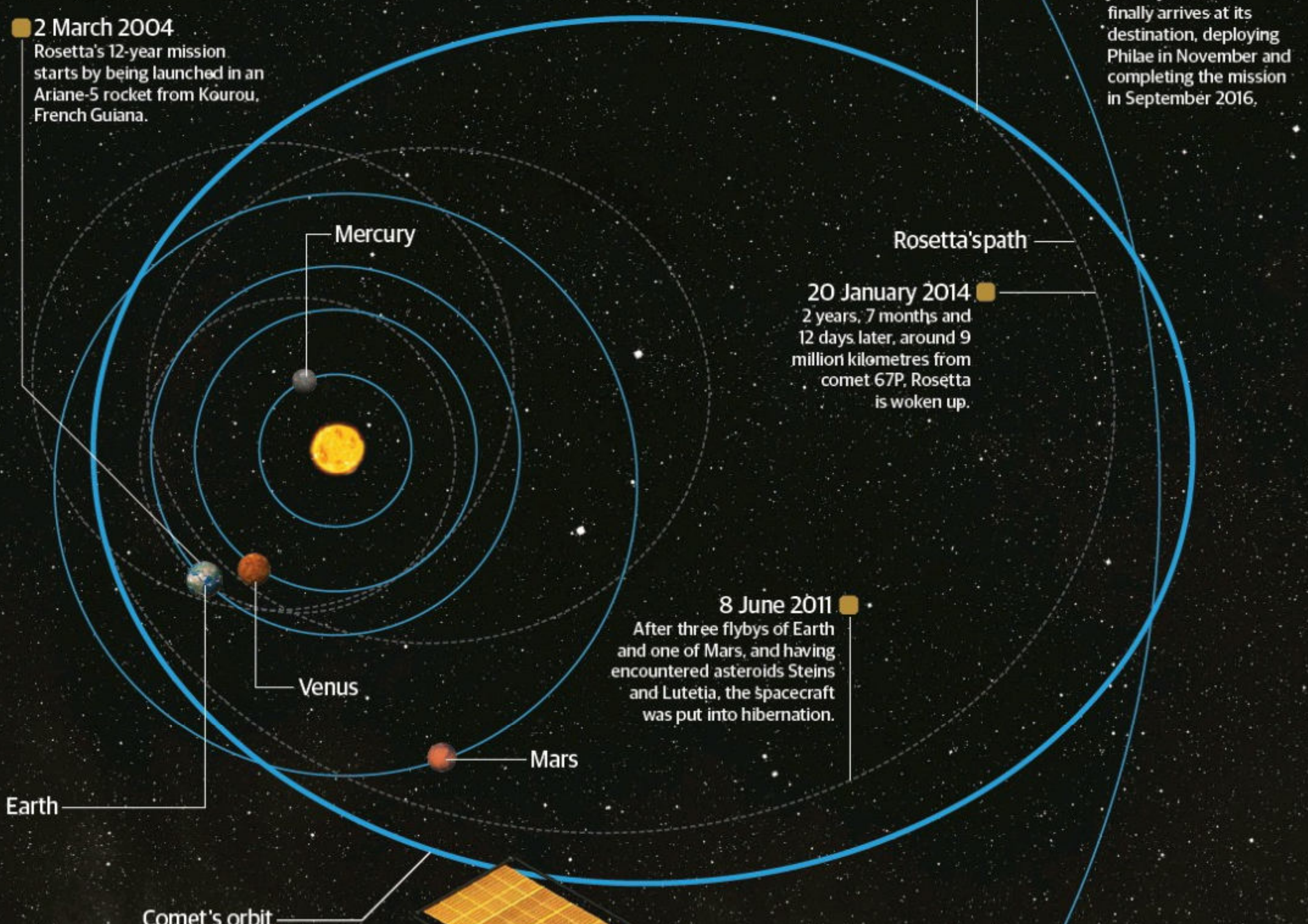
Unfortunately, mostly because of funding constraints, any one mission cannot study its chosen space object in the detail required to fully understand its environment, how it formed and how it behaves. A follow-up mission has a head start, as many of the main features are known before the spacecraft even leaves the launchpad. Buratti adds that "NASA has a leg up on the mission, as we're

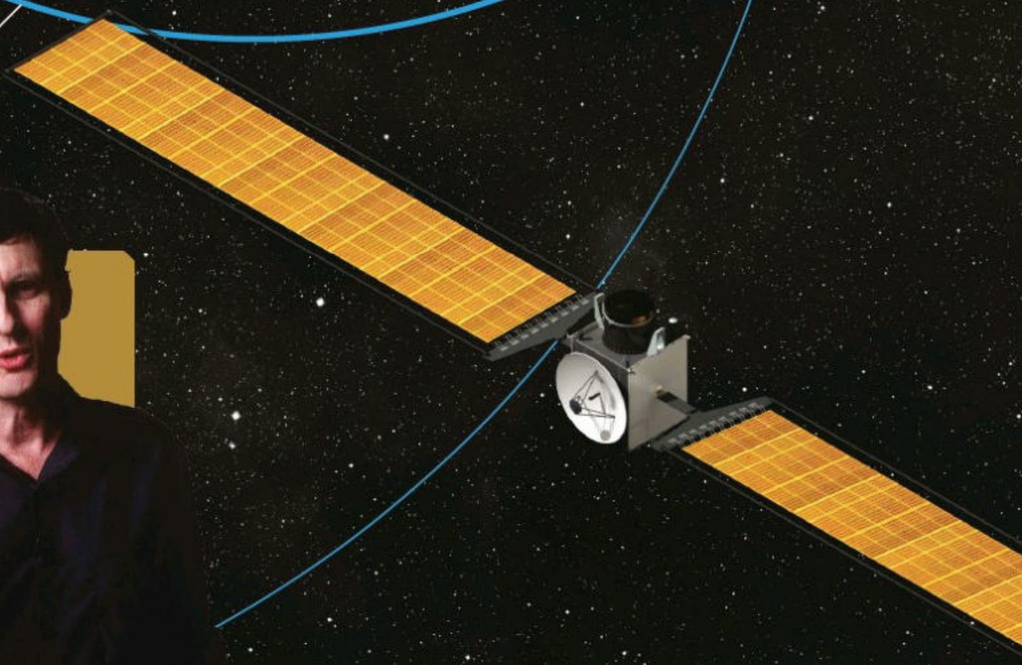
"Studying this material will enable us to peer back in time to the very earliest phases of the planets' formation" **Bonnie Buratti**

The Rosetta team celebrating on receiving signal from Rosetta after 31 months of deep-space hibernation

The CAESAR spacecraft

A sample return mission to follow-up on when Rosetta made the remarkable journey to a comet

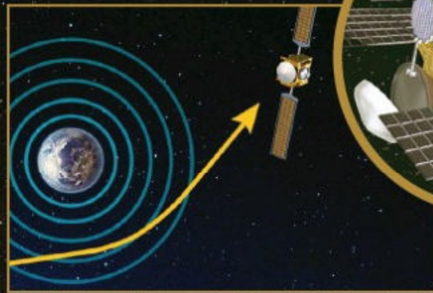




CAESAR's team leader

Steve Squyres
Principal Investigator
Professor of Physical Sciences at Cornell University, Squyres has a strong background in space missions, having worked on spacecraft that have visited Jupiter, Saturn, Venus and Mars.

CAESAR at the ready!
CAESAR will deploy a robotic arm to collect samples of the comet's surface. Samples will be stowed in a sealed capsule for return to Earth.

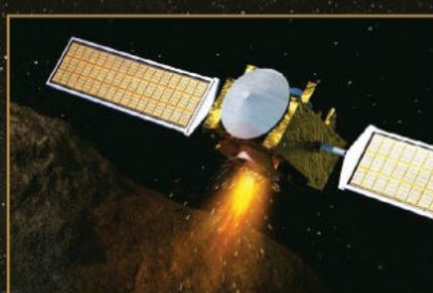


Heading to comet 67P/Churyumov-Gerasimenko
Launching by 2025, CAESAR's space transit will take four years, compared to Rosetta's ten, for it to catch up with 67P in space.

Sample return capsule
CAESAR will store its precious collected comet samples in a thermally stabilised sealed capsule based on the design used by JAXA's Hayabusa mission.

Touch-and-go manoeuvres
CAESAR will use touch-and-go sampling, similar in concept to that due to be used by OSIRIS-REx later in 2018, to capture pieces of the comet.

Grabbing some comet dust
Compressed nitrogen gas jets will be used to force at least 80 grams of the surface of 67P into the sample return capsule.



Returning the sample to Earth
CAESAR's sample return capsule is expected to be jettisoned back to Earth in 2038 for a safe touchdown in Utah.

CAESAR's aims to...

Study a comet up close
CAESAR aims to robotically capture at least 80 grams of comet 67P's surface, separating the rock and ice before returning the sample back to Earth for analysis.

Find out about the origins of life
The mission will study organic-rich samples to understand how comets might have contributed to the delivery of compounds essential for life on Earth.

Discover the source of Earth's water
CAESAR will investigate whether Earth's water came careering through space in a comet, and whether it was eventually delivered by an impact in the distant past.

Uncover more about the formation of comets
Add to the wealth of information gained to understand more about the formation of comets in the early Solar System.

Artist's impression of the Stardust spacecraft chasing comet Wild-2 to capture a sample

already pretty familiar with this comet."

Before Rosetta approached 67P, very little was known about it. In fact, the mission team had to build a spacecraft capable of landing on a comet which they did not even know the shape of, or how hard or soft its surface was. Squyres went on to say: "Being able to design CAESAR for a comet whose properties are well known in advance provides enormous risk reduction. We can tailor all aspects of CAESAR to a comet we know, dramatically reducing mission risk and allowing us to collect and return the best sample possible."

67P's proximity to Earth also makes it a superb target for future comet missions. It is a short-period comet, making its journey around the Sun once every 6.45 years, meaning there are frequent opportunities to chase it down in the relatively near-Earth environment. This not only makes mission timelines shorter, but considerably cheaper too. The vast majority of comets are simply too far away to

> "We can tailor all aspects of CAESAR to a comet we know, dramatically reducing mission risk" **Steve Squyres**

be visited and returned from in human lifetimes. Added to this is the issue of keeping in touch with spacecraft in deep space; communicating with instruments at such distances is no simple matter, not to mention the decrease in solar energy as the spacecraft gets farther from the Sun.

The Rosetta mission achieved a great deal, uncovering details on the structure, composition and behaviour of comets. Nonetheless, returning a sample of 67P to Earth would greatly accelerate our understanding of it, and other comets, as the material can be studied in unprecedented detail. Wright says: "As a scientist who has spent a large part of his career studying extraterrestrial materials in the laboratory, the chance to get samples of 67P back to Earth would be a dream come true."

The alternative to returning samples is to make the measurements in space, as Rosetta did. However, one of the downsides to this is that the measurements are made in unfavourable conditions. Let's just consider the fact that Rosetta's Philae lander, with its sophisticated suite of instruments, made its analyses either when bouncing across the comet's surface, or when sitting precariously on its side. All the while, 67P was hurtling towards the Sun, getting hotter and more active as it went, with

The OSIRIS-REx spacecraft contacts asteroid Bennu for a touch-and-go sample collection

"Having samples of a comet available for bigger, more capable instruments on Earth is of great benefit to science" **Matt Taylor**

boulder-sized rocky material moving around and off its surface. It is a miracle it managed to achieve so much!

Additionally, spacecraft have to deal with a low-gravity environment and extremes of temperature, factors which do not help to create ideal laboratory conditions. Returning those same samples to Earth and analysing them in our advanced, climate-controlled laboratories offers huge advantages for measurement precision and accuracy.

Dr Matt Taylor, ESA's Rosetta project scientist says: "Having samples of a comet available for bigger, more capable instruments on Earth is of great benefit to science. CAESAR will certainly benefit from the detailed information Rosetta has with respect to the comet morphology, and it will be very interesting to compare the CAESAR and Rosetta data."

The advantage of having physical samples on Earth are that they can be carefully studied before analyses begin, but they can also be reanalysed. After all, there are still kilograms of Apollo samples available decades after they were collected, which will be accessible to many future generations of scientists.

Returning a sample from any object in space is a complex operation. In fact, sample return can be thought of as two missions in one; the spacecraft not only has to get there, but also back again. In the early days of planning the Rosetta mission it was hoped it would be a sample return mission, but as time went on - and costs and complexity escalated - the grand plans had to be reigned in. In the end, Rosetta successfully made critical measurements on the comet surface instead, so all was not lost.

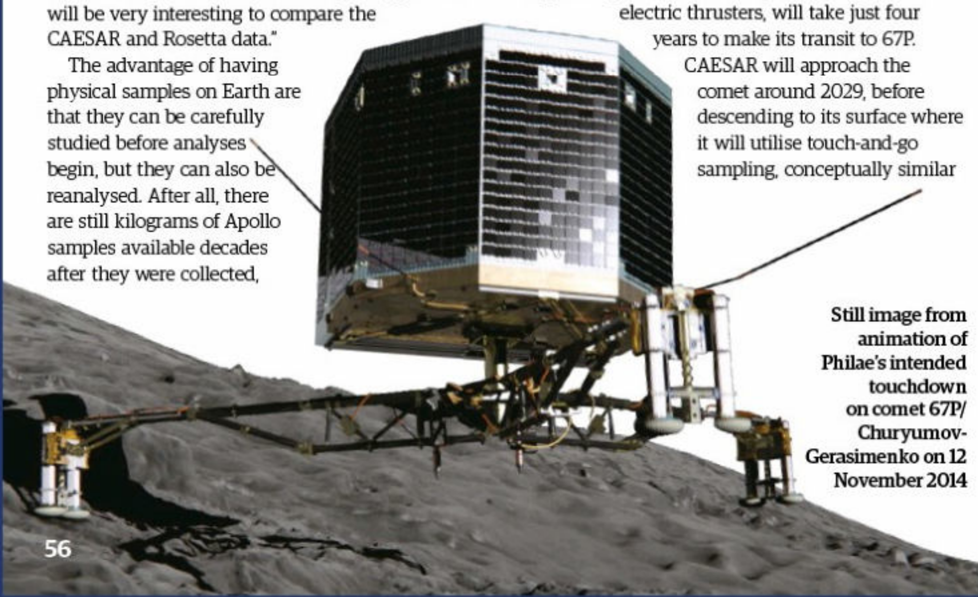
If CAESAR is successful in winning the final round of funding to get to the launchpad then its journey will only have just begun. The spacecraft, supplied by Orbital ATK and powered by solar-electric thrusters, will take just four years to make its transit to 67P. CAESAR will approach the comet around 2029, before descending to its surface where it will utilise touch-and-go sampling, conceptually similar to that planned for OSIRIS-REx. Using compressed nitrogen gas jets, precious material from the surface of the comet will be driven into the sample capsule.

Squyres explains: "CAESAR will collect at least 80 grams of comet surface material. That number is a minimum; tests of our Sample Acquisition System have routinely yielded 200-400 grams of material. Importantly, we will preserve and return to Earth both the solid sample and any gases that evolve from it after it has been stowed, enabling us to investigate both non-volatile and volatile cometary materials."

The sample will be stored in a sealed, thermally stabilised capsule provided by The Japan Aerospace Agency (JAXA), which is closely based on the design used by their Hayabusa spacecraft to return a sample of asteroid 25143 Itokawa to Earth in 2010.

Taylor went on to say "The potential for volatile sample return is interesting, but it's a massive challenge to ensure the samples aren't 'modified' in any way during their return to Earth." It is imperative that the precious pieces of comet are kept pristine. After all, the scientists want to investigate the samples for organic compounds related to life and certainly do not want to risk compromising their measurements with 'Earthly' bugs. When discussing the returned samples, Buratti commented: "Of particular interest are molecules that can form only in very cold places, such as molecular oxygen and nitrogen, and organic molecules that are the building blocks of life."

The treasured sample return capsule would be expected to arrive back in Utah in 2038 after a parachute-assisted landing, kicking off the major phase of scientific investigations. Once the samples are safely stowed in a laboratory, the careful work must begin to study and analyse them in painstaking detail, something which will be an international effort. In the meantime, the CAESAR team can only hope that all their hard work pays off so that they can begin their journey to 67P, and then back again.



Still image from animation of Philae's intended touchdown on comet 67P/Churyumov-Gerasimenko on 12 November 2014

Moon Express was one of the final five teams aiming for the Moon

NO WINNER FOR GOOGLE LUNAR XPRIZE ... *YET!*

Officials behind the project have stated that the venture is far from over

After over a decade of research, development and ambition, the $30 million (£21 million) Google Lunar XPrize will go unclaimed. When the competition was launched in 2007, the XPrize Foundation and Google collaborated to metaphorically throw $30 million on the table for any private company that could land a functioning robotic rover on the surface of the Moon. The initial deadline for the competition was set for 2014, but due to some setbacks the deadline has been pushed back to 31 March 2018.

Peter Diamandis, founder and executive chairman of XPrize, and Marcus Shingles, chief executive officer of XPrize, have recently announced that none of the remaining five teams will make a last-ditch attempt to make the winning 'moonshot'; no team has the capability to send a robotic visitor to the lunar surface. Fortunately, there have been many benefits to the competition, most noticeably a widespread catalyst for space innovation and improvement. This is not to say that the competition is completely over though, as there are a few possibilities to consider in the continuation of this competition.

The need for a challenge has inspired many engineers and entrepreneurs in a time where we are in need of low-cost methods for robotic space exploration. In the process, hundreds of jobs were created, the first commercial space companies were set up in India, Malaysia, Israel and Hungary, there were many education programs for young people all around the world as well as a first-ever mission approval by the United States government to launch a private spacecraft beyond Earth's orbit.

Originally, 29 teams were registered and raring to go. After a decade of tackling the challenge, the list wilted down to just five candidates at the final stretch. The Israeli company SpaceIL, Moon Express in the United States, India's TeamIndus, HAKUTO in Japan and an international group called Synergy Moon.

Even though none of these teams could win the lavish $30 million, $300 million (£210 million) was raised in the process through government contracts, corporate sponsorships and venture capital. $6 million (£4.2 million) was also given out to various teams as a reward for reaching certain milestones.

However, this doesn't mean the end, as XPrize has stated that they're "exploring a number of ways to proceed from here". It could be that all they need to do is find a new title sponsor to provide the generous prize, continuing in Google's footsteps. It could also be the case that they will continue the Lunar XPrize as a non-cash competition, but instead will follow and promote the teams as they reach for the Moon.

"In conclusion, it's incredibly difficult to land on the Moon. If every XPRIZE competition we launch has a winner, we are not being audacious enough, and we will continue to launch competitions that are literal or figurative moonshots, pushing the boundaries of what's possible," say Diamandis and Shingles. "We are inspired by the progress of the Google Lunar XPRIZE teams, and will continue to support their journey, one way or another, and will be there to help shine the spotlight on them when they achieve that momentous goal."

THE FORGOTTEN FORCE

A seemingly weak magnetic entity could have made all the difference in our universe's evolution

Written by Abigail Beall

Earth is held in its orbit around the Sun, like other planets around their own stars. Stars themselves are held in galaxies by larger, more massive objects like the supermassive black hole at the centre of the Milky Way. Behind all of this, the glue that holds galaxies together, is the force of gravity.

Yet, gravity is not the only force that matters when it comes to the structure of galaxies and the space between them. For years, the interstellar magnetic fields were thought to be so weak they made no difference to how our galaxy evolved. However, research is increasingly showing that magnetic fields in galaxies are important to the way space is shaped. They have become a forgotten force that brings countless mysteries - and problems - just waiting to be solved.

While the effects of our own planet and star's magnetic fields can be felt on Earth, the magnetic fields of galaxies are much weaker. In fact, physicists did not expect galaxies to have their own magnetic fields until they were first discovered in 1949 when the polarisation of light coming from stars was measured - caused by a magnetic field. The grains of dust of interstellar space are lined up in one direction, like millions of tiny compasses pointing north, creating this polarisation.

Now we know much more about these magnetic fields, but much still remains a mystery. Stretching out in the vast nothingness of space, interstellar magnetic fields can be weaker than fridge magnets, but their effect is very important. There are a few mysteries that make more sense when this tiny effect is taken into account. Even though it is a small effect, any kind of magnetic field would have an impact on the way charged particles move, therefore altering the shape of the galaxies and the universe.

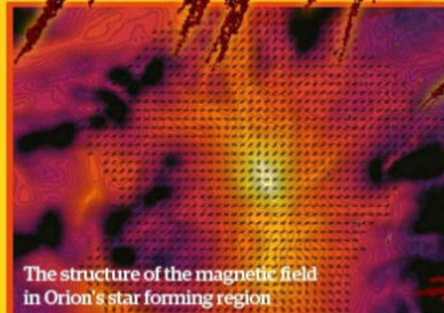
Magnetic fields permeate through interstellar space; regardless of their small size they affect the evolution of galaxies and galaxy clusters and make up a significant part of the pressure of interstellar gas. They are also essential for the onset of star formation and can control the density and distribution of cosmic rays throughout the interstellar medium, since cosmic rays are made up of charged particles.

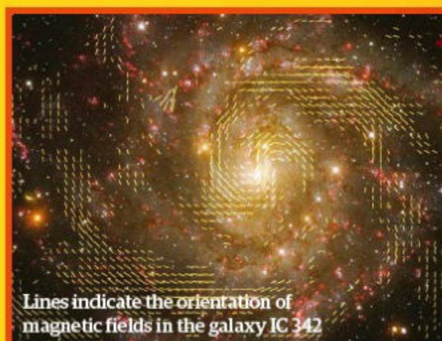
Galaxies have their own magnetic fields. Take an example close to home. The Milky Way's overall magnetic field is a few microgauss - a few millionths of a gauss. This is around 100,000-times smaller than the field at Earth's surface. Our own galaxy's magnetic field is maintained and made stronger by a dynamo; charged particles move across the magnetic field as the galaxy spins, creating an even stronger magnetic field.

Our galaxy is not the only one to have its own magnetic field, however. Much younger galaxies have shown evidence for them too. In August last year, a published paper showed evidence for a microgauss magnetic field in a galaxy almost 5 billion years ago.

But, one mystery still remains - how the magnetic fields got there in the first place. "These models do indeed require a seed magnetic field," says Lawrence Widrow, professor of astronomy at Queen's University in Kingston, Canada. "That is, they can amplify an existing field but can't generate magnetic fields when non exist." How strong these initial seed fields must have been is unknown, says Widrow, because we do not know how long each galaxy has taken to build up the magnetic field it currently has now.

The question of where these seed magnetic fields arose from comes down to two options, says Professor Bryan Gaensler from the Dunlap Institute for Astronomy and Astrophysics. "There needs to be some sort of initial seed field," he says, "but we don't know if this comes from 'astrophysics' - from stars, gas clouds and black holes creating and then expelling their magnetic fields - or if it comes from 'cosmology' - some exotic process in the early universe that generated weak magnetic fields."


The structure of the magnetic field in Orion's star forming region


Lines indicate the orientation of magnetic fields in the galaxy IC 342

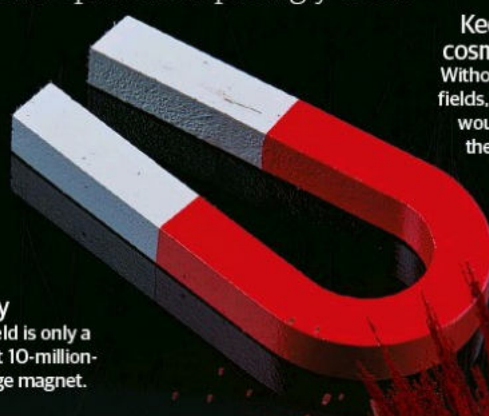
"We don't know if this [field] comes from 'astrophysics', or if it comes from 'cosmology'" **Bryan Gaensler**

Weaker than a fridge magnet

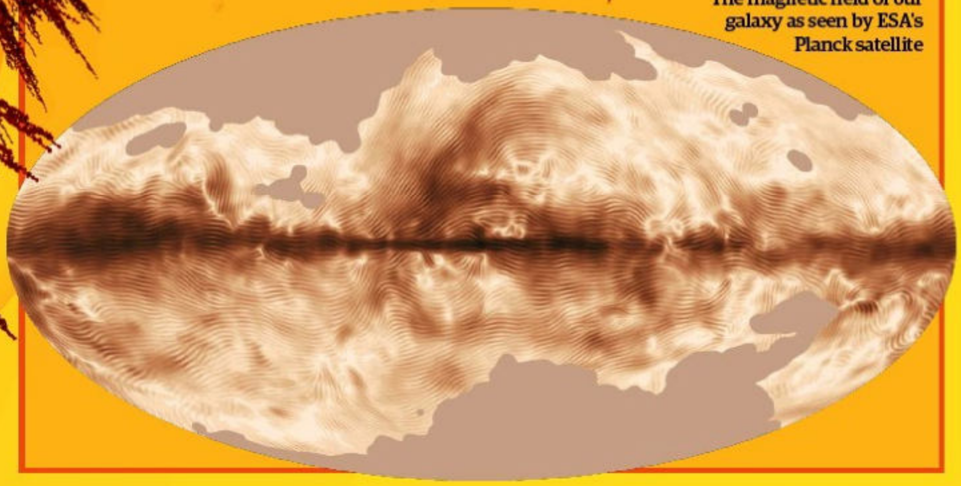
The magnetic force that permeates interstellar space is surprisingly weak

In terms of gauss
A strong fridge magnet has a magnetic field of 100 gauss.

Keeping the cosmic rays in
Without magnetic fields, cosmic rays would fly out of the Milky Way.



The weak Milky Way
Our galaxy's magnetic field is only a few microgauss, or about 10-million-times smaller than a fridge magnet.



The magnetic field of our galaxy as seen by ESA's Planck satellite

There have been numerous proposals for generating primordial fields through cosmology. In 1988, Widrow and his colleague Michael Turner published a paper that said these kinds of magnetic fields could be produced in the very early universe, during an epoch of inflation - when space expanded exponentially. Inflation is an important time in terms of the development of the universe - it is thought that large galaxy structures were caused by quantum fluctuations in energy during this epoch. However, the theory is not straightforward. "Our proposal required modifications to the laws of electromagnetism, and therefore requires some rather exotic physics," explains Widrow.

When it comes to astrophysics, there are also options. "One can produce magnetic fields in the first generation of stars through something called the Biermann battery," says Widrow. The process, discovered by Ludwig Biermann in 1950, starts out with a plasma made up of electrons and protons. If the plasma is hotter on one side and denser on the top than the bottom, the electrons will start to drift to the colder temperature, lower density side faster than the protons, because they have a lower mass and lower inertia. This movement of charge will create a magnetic flux.

"Since the timescale for a star to rotate is very short compared to cosmic timescales, these fields can be rapidly amplified via a stellar dynamo," says Widrow. The solar activity of our own Sun is an example of a stellar dynamo in action. "If the star then explodes as a supernova, its fields will be expelled into the interstellar medium."

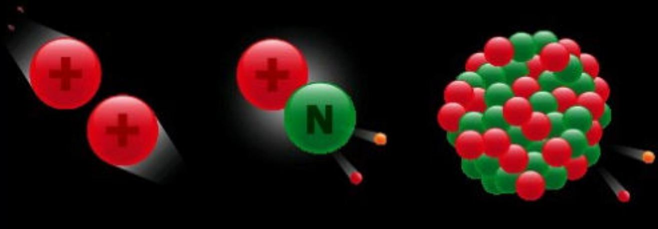
Another option is that the fields were produced in the early population of active galactic nuclei, which are then driven out into the intergalactic medium by AGN jets. Yet another possibility is that fields were generated during the earliest stages of galaxy formation.

However, when it comes to the question of astrophysics or cosmology, "we are yet to obtain any data at all that might point toward one culprit over another," says Gaensler.

The problem is, it is incredibly difficult to gather evidence. "Both cosmological and astrophysical processes could generate initial weak magnetic fields, but we don't know which ones actually operated, and which ones ended up contributing to the magnetic fields we see today," says Gaensler.

Fundamental forces of the universe

There are four forces which, between them, are responsible for every interaction in the cosmos

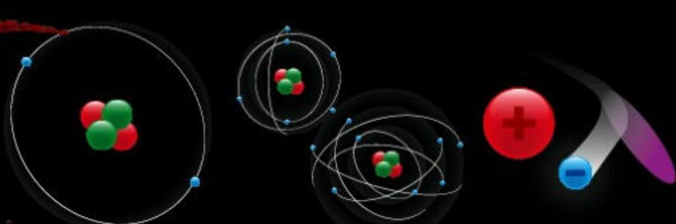


Weak nuclear force

The 'weak' force is actually the third weakest of the four. It is responsible for the way subatomic particles interact and the cause of radioactive decay.

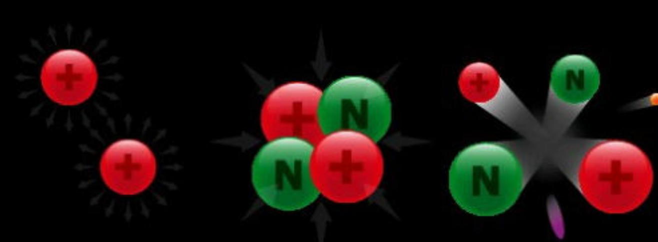
Gravitational force

This is a force that attracts objects with a mass to each other - it's what keeps the planets in orbit around the Sun. It is the weakest of all four forces.



Electromagnetic force

Responsible for the interactions between charged particles, the electromagnetic force includes both electricity and magnetism.



Strong nuclear force

Holds most matter together by binding quarks together into hadrons. It only works at tiny distances, but at these distances it is the strongest force.

Our magnetic universe

From tiny planets to colossal black holes, a variety of objects across the universe produce magnetic fields

Our home planet

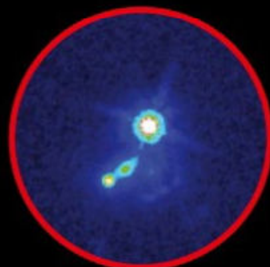
Strength of magnetic field:
0.25 to 0.65 gauss
Size of magnetic field:
63km on one side and 130km on the other

Earth's magnetic field is generated by liquid iron moving around in the outer core. The shape of the field is distorted by the solar wind.

Sagittarius A*

Strength of magnetic field:
202 gauss at the core
Size of magnetic field:
150 light years

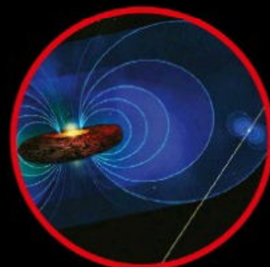
Roughly 150 light years from the black hole's core, the field is only one-hundredth of the strength of the magnetic field around Earth.



CLASS B1152+199

Strength of magnetic field:
Around a few microgauss
Size of magnetic field:
Uncertain

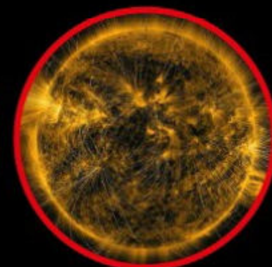
Last year, astronomers found a galaxy nearly 5-billion-light-years away with a magnetic field of a similar strength to that of the Milky Way.



The Milky Way

Strength of magnetic field:
A few microgauss
Size of magnetic field:
6 to 40 microgauss

The average strength of the magnetic field in the Milky Way is about six microgauss near the Sun and increases to 20 to 40 microgauss in the galactic centre.



The Sun

Strength of magnetic field:
3,000 gauss on sun spots
Size of magnetic field:
The size of the Solar System

The Sun has two magnetic poles, like a huge bar magnet, which create its field. The poles flip at the peak of the solar activity cycle every 11 years.

> "Magnetic fields could be produced in the very early universe, during an epoch of inflation"

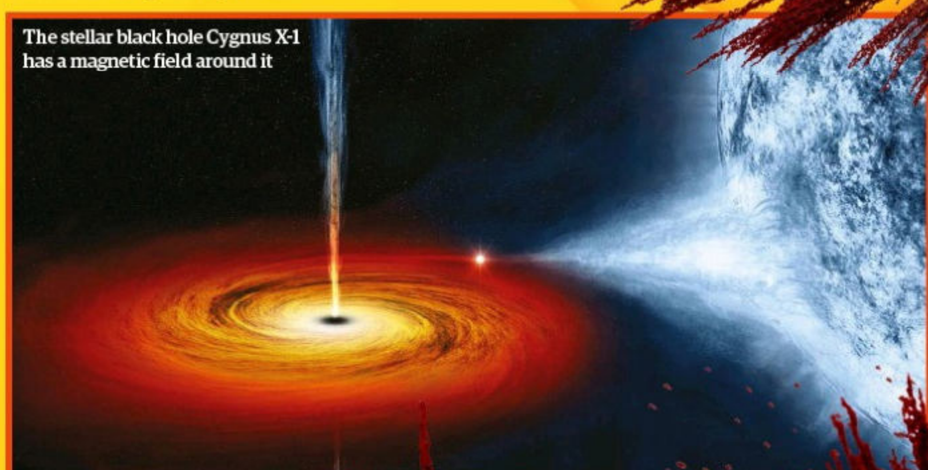
One of the best ways of searching for magnetic fields is by looking for radio waves. The strength of a magnetic field can be deduced from synchrotron emission - electromagnetic radiation emitted when charged particles are accelerated radially - the polarisation of the radiation can be used to work out the plane of the magnetic field. The Zeeman effect, the way light splits into different spectra in the presence of a magnetic field, can be used to work out the magnetic field of cold clouds of gas.

ESA's Planck space observatory, which orbited the Earth from 2009 to 2013, studied the universe at far-infrared, microwave and high-frequency radio frequencies with high sensitivity to probe cosmic microwave radiation. In January 2017, evidence gathered by Planck revealed gigantic loops of magnetism and other structures that point to a magnetic dynamo at work in the Milky Way.

Then, in March last year, a group of German astronomers used the 100-metre-diameter radio telescope at Effelsberg to observe several galaxy clusters. At the edges of these large accumulations of stellar systems, hot gas and charged particles, they found the most extended magnetic fields in the universe known so far.

The telescope is still searching for more evidence. "The Effelsberg radio telescope proved again to be an ideal instrument to detect magnetic fields in the universe," said Rainer Beck from the Max Planck Institute. "Now we can systematically search for ordered magnetic fields in galaxy clusters using polarised radio waves."

The Low-Frequency Array, or LOFAR, is a large network of radio telescopes that is being used to study fields in galaxies that formed early on in the universe, but as of yet, nothing conclusive has been found. "Unfortunately, the only data we have on magnetism in the early universe are upper limits - non-detections," says Gaensler. Once we understand the universe's magnetic field in more detail, it will help us to understand and model other aspects of the universe too. For example, models of how galaxies evolved could benefit from including a value for the magnetic field, even if it has long been ignored.



The stellar black hole Cygnus X-1 has a magnetic field around it

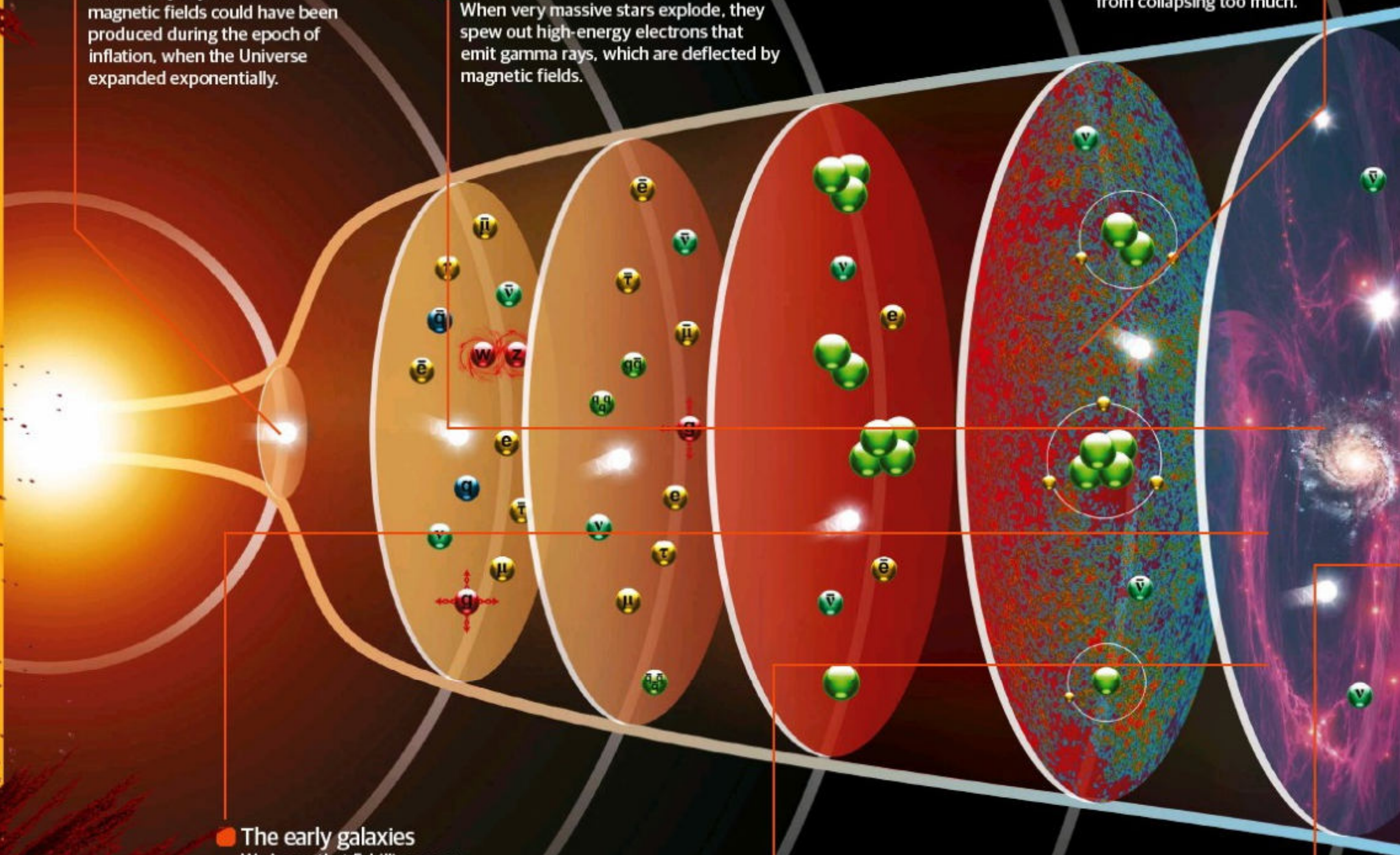
How magnets shaped the universe

These guardians of the galaxy have allowed intelligent life to flourish

Inflation
One theory says that seed magnetic fields could have been produced during the epoch of inflation, when the Universe expanded exponentially.

Supernova explosions
When very massive stars explode, they spew out high-energy electrons that emit gamma rays, which are deflected by magnetic fields.

The formation of stars
Magnetism is essential for stars, like our sun, to form, by preventing clouds of gas from collapsing too much.



The early galaxies
We know that 5-billion-years ago, galaxies already had magnetic fields as strong as that of our own galaxy.

Intergalactic medium
The pressure in the intergalactic medium is partly maintained thanks to the magnetic fields permeating through it.

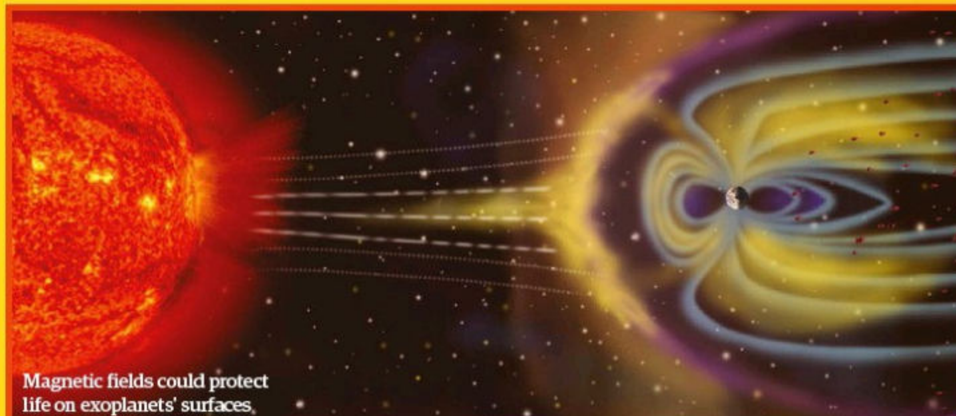
Key

Spiral galaxies
Some evidence suggests the arms of spiral galaxies are formed because of magnetic fields.

Formation of the planets
The movement of grains of dust around stars like the Sun, that eventually form planets, are highly influenced by magnetic fields.

Evolution of life on Earth
Our planet's magnetic field protects us from the harmful cosmic rays that race through space.

Magnetic field data from the Whirlpool Galaxy (M51)



Magnetic fields could protect life on exoplanets' surfaces

"Once we understand the universe's magnetic field, it will help us to understand other aspects of the universe"

But first, we must gain greater insight into its history. This is why more evidence needs to be gathered before conclusions are drawn.

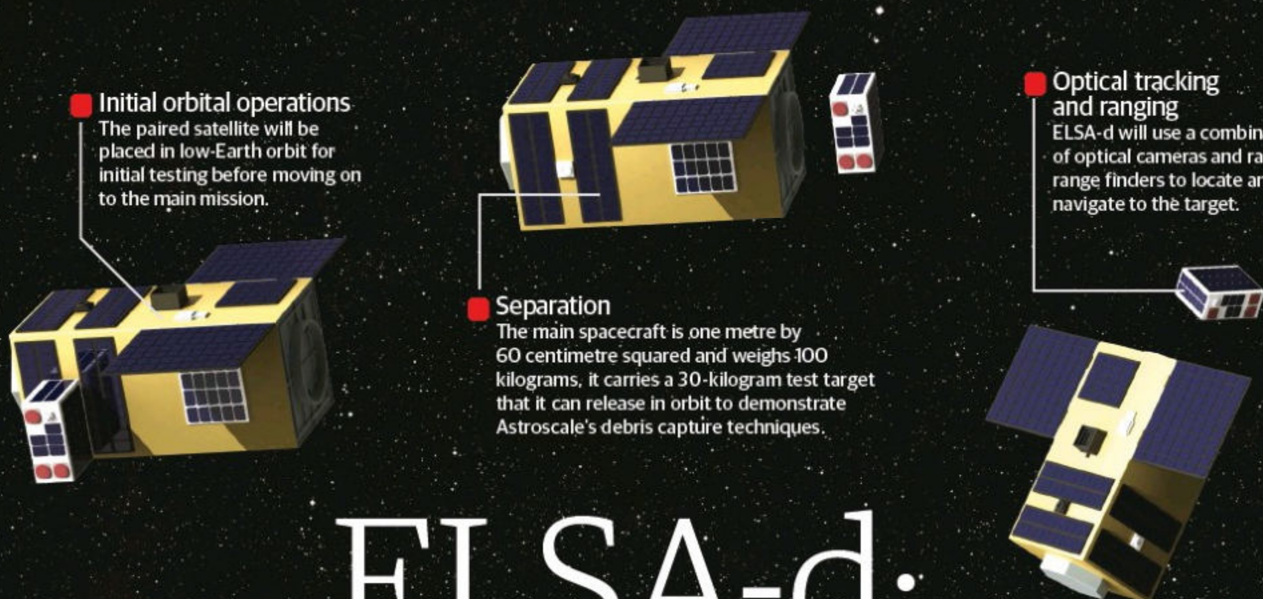
If telescopes can find evidence of strong magnetic fields in proto-galaxies, the masses of dust and gas that clump together to form galaxies, it would indicate the magnetic fields were formed during inflation or in the early active galactic nuclei. However, if the first fields are found in already formed galaxies, this could mean the magnetic field has originated from early stars.

NASA's flying observatory SOFIA is currently getting ready to spend 2018 observing the magnetic field of distant stars in the hope of understanding more about how magnetic fields shape the formation of stars.

The Square Kilometre Array (SKA) is an international project to build the world's largest radio telescope. Eventually, the telescopes will sit over an area of one kilometre squared, making it at least five-times more sensitive and 60-times quicker than today's best radio telescopes. This should give astronomers completely new insight into the intensity of magnetic fields across the universe.

As part of its observations, SKA will spend a year looking at the Faraday rotation of millions of galaxies beyond our own. Studying the Faraday rotation - interaction between light and a magnetic field - of the electromagnetic waves can reveal information about the magnetic field over the plane of the line of sight. This will increase the amount of data by five orders of magnitude over current data sets.

"Through the unique sensitivity and resolution of the Square Kilometre Array, the window to the magnetic universe can finally be fully opened," the project website says. Construction of SKA is expected to begin in 2018, for the first observations to be collected in 2020. Hopefully the experiment will be able to give us the insight needed to make the right measurements to finally understand the origin of this forgotten but vital force, and its place in the universe.

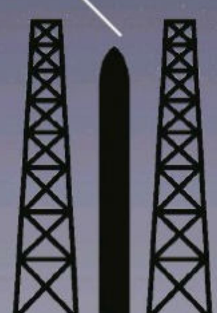


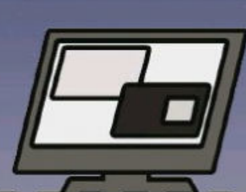
ELSA-d: chasing satellites

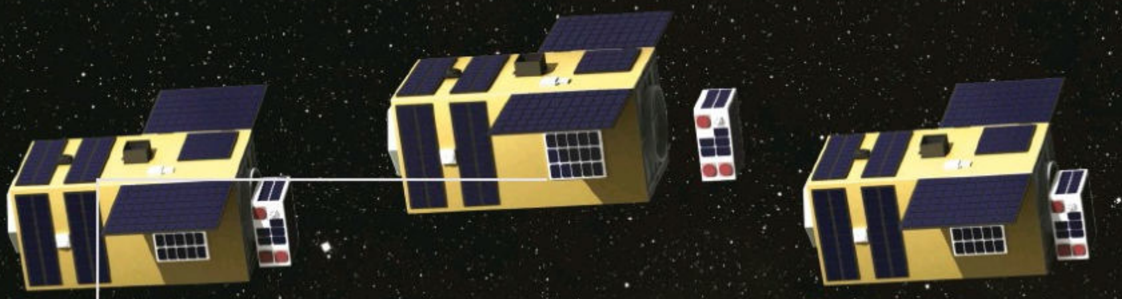
With space debris a growing threat, Singapore-based Astroscale are preparing to test a satellite removal service

Since the launch of Sputnik 1 in 1957, humanity has made more than 5,250 rocket launches, which have sent over 7,500 satellites into space. Many of these missions have left bits behind, from completely dead satellites like the eight-tonne Envisat, to an estimated 166 million pieces smaller than one centimetre. A common problem has been the explosion of used rocket stages as remaining fuels ignite sometime after the payload has been sent on its way. The debris count got a lot worse in 2007 when China fired a missile at one of its own satellites to test the feasibility of shooting down a foreign spy satellite. On top of these, astronauts have lost gloves, tools, cameras and general waste from missions since the start of the space age.

Space debris presents a significant risk to active spacecraft and missions; even the lowest orbits require speeds of over seven kilometres (4.3 miles) per second, getting faster the higher the orbit, and when two objects collide from different orbits their combined speeds create a catastrophic impact. As big as space is, accidental collisions have happened. In 2009, the active American communications satellite, Iridium 33, crashed into the defunct Cosmos 2251 Russian military satellite, and the ISS has often had to move to avoid passing junk. Even the tiniest pieces can cause problems, producing sandblasting-like abrasion; indeed in 1983 one of the Space Shuttle Challenger's windows was cracked by a fleck of paint.





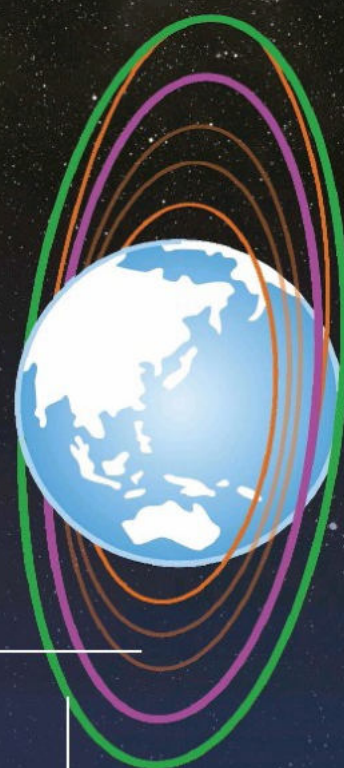


Modern missions pay much more consideration to minimising debris production and the disposal of the craft at the end of a mission. But while the lower orbits are gradually cleaned by the remaining atmosphere dragging debris back in, we do face the risk of a disaster called the Kessler Syndrome. In such a situation the collision of two objects could set off a chain reaction of debris production, filling Earth's orbit with a cloud of junk and preventing future launches. Therefore, it is essential to reduce the mass already floating up there (estimated to be more than 7,500 tonnes) and bring back newly defunct missions, and Singapore-based start-up Astroscale are preparing to do just that.

Ironically their first mission, a nanosat launched in November 2017 to measure the density of the tiny debris not easily tracked from the ground, was lost in orbit due to a launch vehicle failure. However, they are pressing onwards with their next mission, the End-of-Life Service by Astroscale demonstration, or ELSA-d. Slated for launch in the first-half of 2019, ELSA-d consists of a two-part satellite to demonstrate Astroscale's plan to capture and de-orbit dead satellites.

After launch, the metre-long, 100-kilogram primary satellite, the chaser, will separate a 30 kilogram target subsatellite. It will then demonstrate Astroscale's optical tracking and navigation technology to reacquire it, before using their general-purpose docking system to capture the target. After that the chaser will then thrust the target into a disposal orbit where it will be more rapidly de-orbited by atmospheric drag. Primarily Astroscale intend to service companies launching new satellites to reduce the build-up of more debris, but ultimately their system could be used for more extensive cleaning of low Earth orbit. Multiple chaser satellites, possibly driven by solar electric propulsion for longevity, could shunt old satellites into disposal orbits, and save us from being hemmed in by our own rubbish!

> "Astroscale intend to service companies launching new satellites to reduce the build-up of more debris"



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INTERST
VISIT

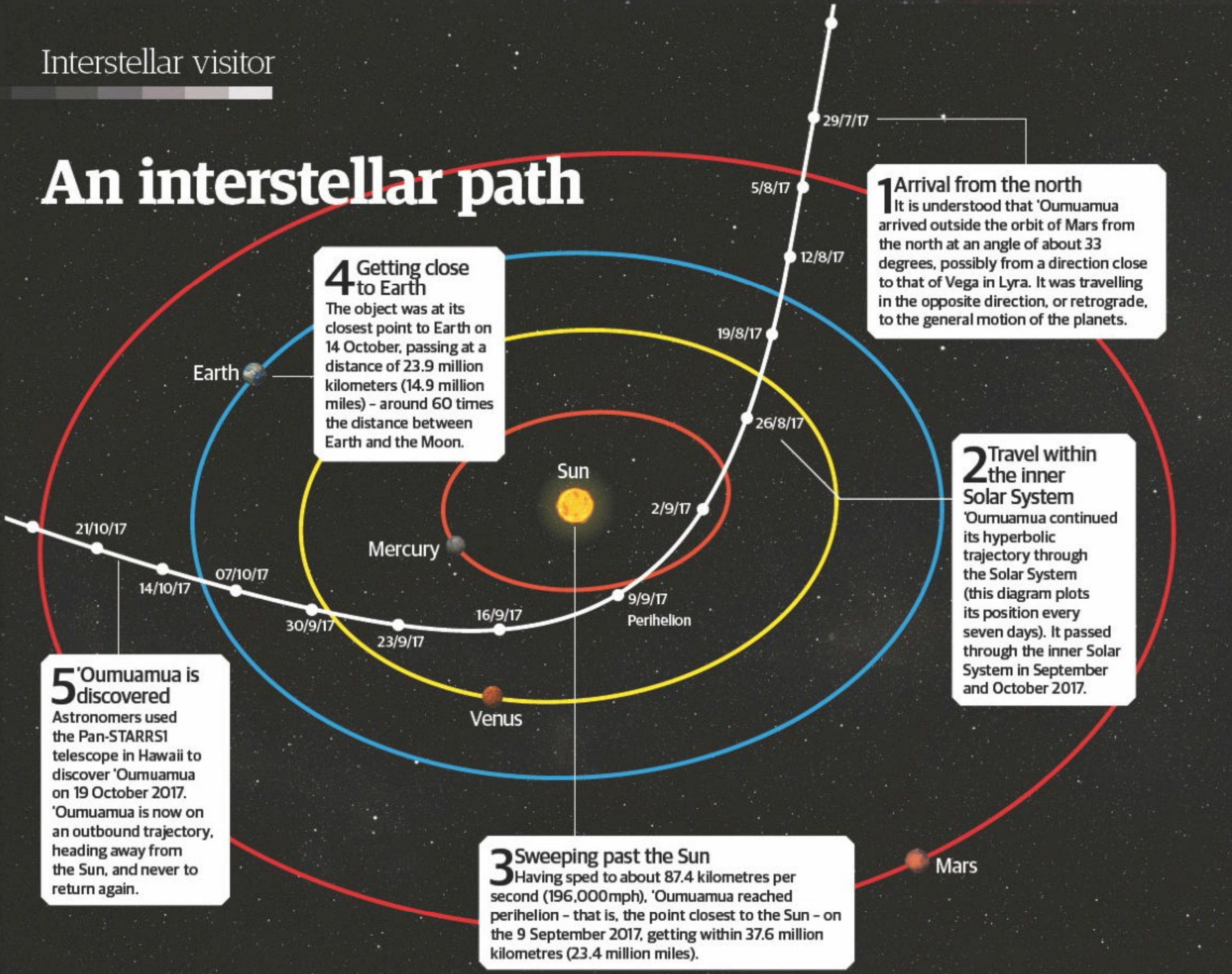
When astronomer Robert Weryk first spotted an unusual object hurtling past Earth, he never imagined it had come from outside our Solar System

Written by David Crookes

© ESO/M.Kornmesser


TELLAR
TOR

An interstellar path



In the hours following 19 October 2017, Robert Weryk was sorting through the images captured by Pan-STARRS1, a 1.8-metre diameter telescope perched at the summit of the massive shield volcano, Haleakalā, on the Hawaiian island of Maui. Looking for evidence of near-Earth objects, he spotted a fast-moving body working its way across the night sky, halfway between the orbits of our planet and Mars. "It didn't have the motion that you'd typically expect from an asteroid or comet," he says. And this sparked his curiosity.

"I contacted a colleague who works at the European Space Agency and he had previously observed it," the astronomer, who works at the University of Hawaii at Manoa, continued. Soon, other astronomers across the world were also looking skywards, using instruments such as the Canada-France-Hawaii Telescope to help figure its trajectory. More poured over data from the Very Large, Gemini South and Keck II telescopes to observe the bizarre objects composition, brightness, shape and colour.

It was quickly discovered that the object had come within 38 million kilometres of the Sun 40 days earlier, turning due to the force of our star's gravity before shooting past the Earth. "It turned out it had come from outside the Solar System," Dr Weryk affirms, as astronomers rushed to use the most sensitive of instruments to gather as much data as possible knowing they had little time to waste. And that, as you might expect, was a startling revelation.

"For decades, we've theorised that such interstellar objects are out there, and now - for the first time - we have direct evidence they exist," said Thomas Zurbuchen, associate administrator for NASA's Science Mission Directorate in Washington. "This history-making discovery is opening a new window to study formation of solar systems beyond our own."

Data from these observations has given astronomers an intriguing glimpse of how the particular, intriguing object looks and what it is potentially made up of. Images from the FOcal Reducer and low dispersion Spectrograph (FORS) instrument on the Very Large Telescope, combined with those of other large telescopes, for instance, picked up on an unusually large variation in brightness - a brightening and darkening light curve that varies by a factor of ten as it spins on its axis every 7.3 hours, says Karen Meech, of the Institute for Astronomy in Hawaii with researchers believing these types of visitors pass through once a year, they tend to be too small and too faint to see.

This is unlike any other known comet or asteroid in our Solar System, and it points to the object having a highly elongated shape. Indeed, it has been shown to be a rocky, cigar-shaped object up to 400 metres (1,312 feet) long. But this object appears to be as much as ten-times as long as it is wide, something NASA points out is an aspect ratio "greater than that of any asteroid or comet observed in our Solar System to date."

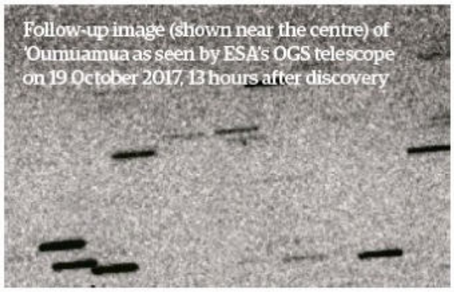
"This history-making discovery is opening a new window to study formation of solar systems beyond our own" **Thomas Zurbuchen**

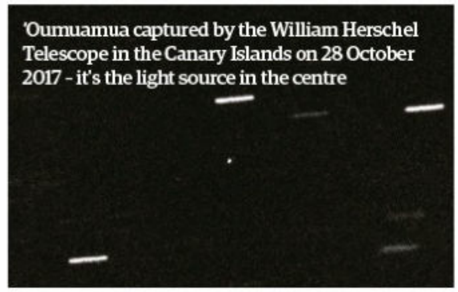
Unsurprisingly, this has also had an effect on how the object is classified. With no evidence of a coma – the cloud of gas that typically surrounds a comet's core – the initial assumption that it was a comet (labelled C/2017 U1) was soon dismissed. It was then reclassified as an asteroid (A/2017 U1), and with a reddish hue and an unsteady brightness it was typical of such bodies.

But with the knowledge that the object's hyperbolic path was going to take it out of the Solar System, and given Dr Weryk and a fellow Institute for Astronomy researcher Marco Micheli's observation that it was going so fast it had avoided being captured by the Sun's gravitational pull, a rethink was needed. The interloper was deemed to be an interstellar asteroid instead and, on 14 November 2017, the International Astronomical Union approved a new designation of I. This strange object became known as 1I/2017 U1.

It was also nicknamed 'Oumuamua, which means "a messenger from afar arriving first" in Hawaiian. Yet more important for researchers was what 1I/2017 U1 was made of, and where exactly it had come from in the universe. This has formed the focus of much scientific attention over the past few months, with studies only really constrained by the fact it is now far too faint to be directly observed.

One of the possibilities – however far out it may seem – is that it is some kind of alien spacecraft. 'Oumuamua's unusual shape, and the fact that it was seen to travel as fast as 315,431 kilometres (196,000 miles) per hour (evidence that suggested it is not gravitationally bound to the Sun and

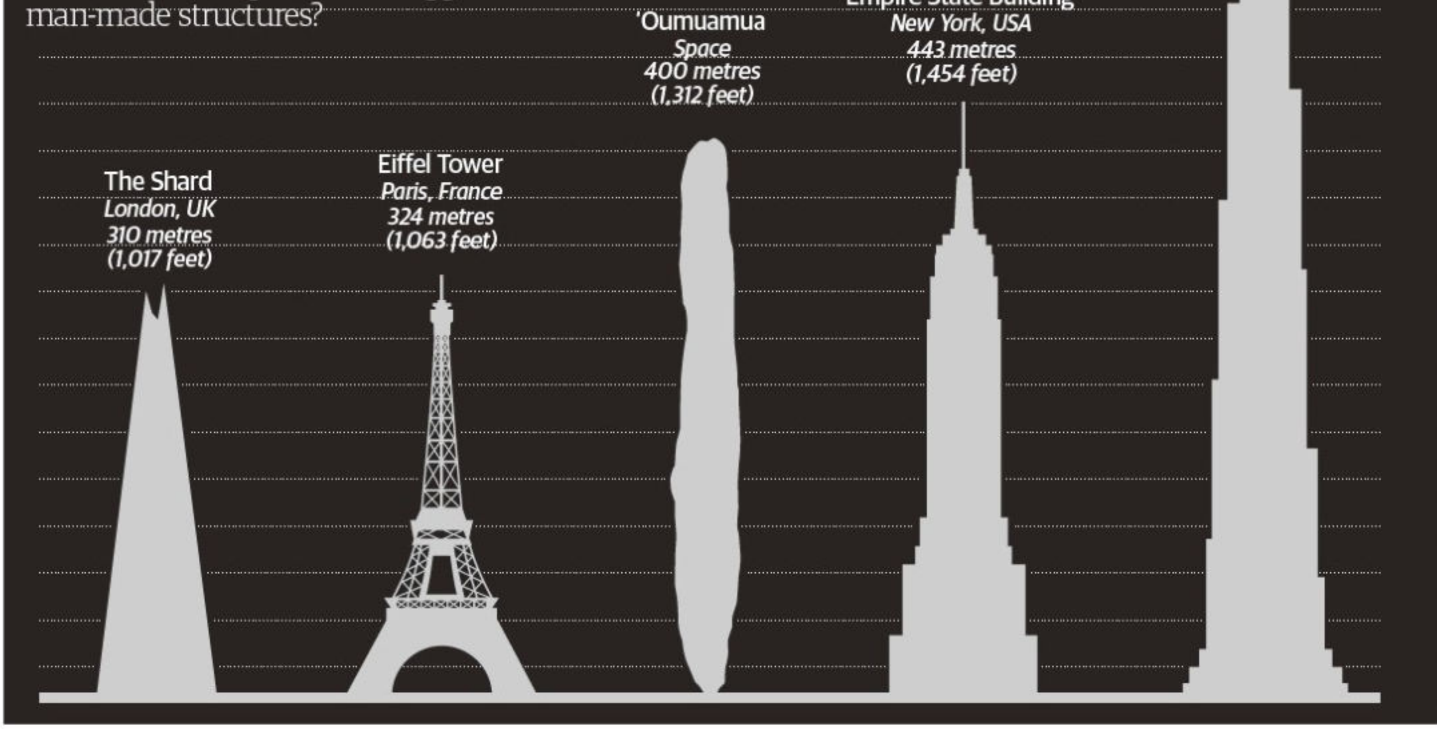

Follow-up image (shown near the centre) of 'Oumuamua as seen by ESA's OGS telescope on 19 October 2017, 13 hours after discovery


'Oumuamua captured by the William Herschel Telescope in the Canary Islands on 28 October 2017 – it's the light source in the centre


It was originally thought 'Oumuamua was a comet like Haley's (pictured) but it did not have a tail or coma

How big is 'Oumuamua?

How does it compare to the biggest man-made structures?




Stephen Hawking led an investigation to see whether 'Oumuamua was an alien probe or a natural phenomenon

"This is unlike any other known comet or asteroid in our Solar System, and it points to the object having an elongated shape"

is, therefore, a visitor) prompted Breakthrough Listen – a global program searching for evidence of civilisations beyond Earth – to use a radio telescope at Green Bank, West Virginia to observe the object.

Scientists used the dish to listen across four radio frequency bands in the hope of detecting non-natural electromagnetic signals. They were working on the assumption that long-distance space transportation would take the form of a cigar shape to minimise friction and damage from interstellar gas and dust (similar to Sir Arthur C. Clarke's fictional Rama from *Rendezvous with Rama*). In the event no signals were detected, so an alien ship has been ruled out for now, although monitoring and analysis is continuing.

That has left scientists to get on with figuring out how nature formed 'Oumuamua and why it seems to be an asteroid rather than a comet. This is particularly important because many astronomers believed an object spotted from outside the Solar System would be a comet, so the idea that it isn't is a little baffling.

For that reason, Professor Alan Fitzsimmons from Queen's University Belfast, Northern Ireland explored such an idea. He led a paper in the journal *Nature Astronomy* that suggested an internal icy composition cannot be ruled out for 'Oumuamua, since it could be covered by "an insulating mantle produced by long-term cosmic ray exposure."

It explores the idea that 'Oumuamua's interactions with the interstellar medium have created the form it displays today. In doing so, it would explain why there was no gas streaming off the surface of 'Oumuamua, nor any dust particles or a tail, even as it travelled relatively close to our Sun.

Just as importantly, it would go some way to explain why Fitzsimmons found 'Oumuamua doesn't look like a typical asteroid, and instead seems to resemble icy objects found in the outer Solar System. A crust of just 50 centimetres would be enough to protect ice at the object's core from the Sun's heat, the researchers discovered.

Such a deep outer crust could have formed over millions of years, giving 1I/2017 U1 a dark-red colour. If true it points to 'Oumuamua having begun life as an icy object in its own system before embarking on its long journey towards our place in the universe. It also shows the fast-moving nature of research into 'Oumuamua, since Meech found it to be completely inert. As a NASA

What we know about 'Oumuamua

While research time was limited, what did we manage to find out?

It's a natural object
Breakthrough Initiatives

Although there had been suggestions that 'Oumuamua could be an alien-made spacecraft, no directed or broadcast radio transmissions were detected from it when the SETI Institute ran tests.

It's likely wrapped in organic insulation
Alan Fitzsimmons, Queen's University Belfast

'Oumuamua is made up of organic ices such as frozen carbon dioxide, methane and methanol. Thanks to long-term exposure to cosmic radiation, a dark-red outer crust some half-a-metre thick appears to have formed over it.

It moves really quickly
Scientific collaboration

Scientists agree that 'Oumuamua was discovered travelling at 87.3 kilometres per second (54.2 miles per second). Since it was on its way out of our Solar System when it was discovered, it soon became too faint to see.

It is tumbling
Karen Meech, astronomer at the Institute for Astronomy, University of Hawaii

Light-curve observations showed 'Oumuamua to have wild swings in brightness by a factor of 10, indicating an irregular, excited tumbling motion that is rarely seen in celestial bodies. It spins on its axis every 7.34 hours.

It's (probably) not a comet
Scientific collaboration

Even though 'Oumuamua did not have a coma or a tail, it was still initially deemed to be a comet. That was dispelled when astronomers saw no signs of cometary activity, but things can change.

The European Southern Observatory's Very Large Telescope in Chile was among those called into action to measure 'Oumuamua's orbit, brightness and colour

What we want to know about 'Oumuamua

What is really inside it

Alan Fitzsimmons, an astronomer at Queen's University Belfast, says questions about its interior structure remain unanswered. "Is there really water ice inside?" he has posed. "We'll probably never know for sure."

Where it has come from

'Oumuamua may have originated from the star Vega in the northern constellation of Lyra, but Fabo Feng, a postdoctoral fellow at the University of Hertfordshire, reckons it could have come from the Pleiades group of young stars.

Why it has extreme proportions

'Oumuamua is an oblong shape with a length that is ten-times its width, a ratio not found within our Solar System. The most elongated objects we have seen until now have been no more than three-times longer than they are wide.

How it came to be ejected

Scientists would love to know how 'Oumuamua ended up leaving its own galaxy. Perhaps it was ejected from a forming star, or maybe it ended up being flung away due to a high-energy collision. Another theory even involves being ejected from within a binary star system.

How many similar objects there are

Scientists are convinced that 'Oumuamua is not a one-off, and some even suggest there could be as many as 46 million such interstellar objects – or maybe even more – all waiting to be discovered.

statement suggests, it was seen to be dense, composed of rock and possibly metals with no water or ice.

One thing that is entirely agreed on, however, is that 'Oumuamua is spinning chaotically. Dr Wesley Fraser from Queen's University Belfast says his team came to such a conclusion by studying variations in 'Oumuamua's brightness over time. "At some point or another, it's been in a collision," he concludes, although when that was is still to be determined.

All he can say is that it may have happened in its own stellar system and that the tumbling will continue for at least a billion years. "The tumbling actually causes stresses and strains internal to the object, and that slowly but surely squeezes and pulls on the object – just like tides on the Earth – to remove energy from the spin," he says. If only, he muses, there had been more time to get a high-resolution image that could show an impact crater. As it was, astronomers had just two weeks before it disappeared from the view of optical telescopes, so it really was a case of collecting as much data as possible before our visitor was out of sight.

Chances are, however, that astronomers may get more chances to pick up on similar objects, especially when the Large Synoptic Survey Telescope, with a 8.4-metre primary mirror, is built in Chile. A new study being considered for publication in *The Astrophysical Journal* suggests our Solar System contains many thousands of visiting interstellar asteroids, all waiting to be picked up. The paper's researchers, Manasvi Lingam and Abraham Loeb, call our Solar System a "fishing net" and say interstellar comets "can be potentially distinguished by their differing ratios of oxygen isotopes through high-resolution spectroscopy of water vapour in their tails."

How 'Oumuamua came to be formed continues to be a source of intrigue. Meech says 'Oumuamua could have been created by a supernova explosion, or it may have been formed by two objects colliding and merging. How it was expelled from its own system is also being researched. It initially seems to have appeared from the direction of Vega, the brightest star in Lyra and, if so, it would have taken more than 300,000 years to reach us, but this is a source of debate. It is also possible that parts of our own Solar System are in interstellar space.

For now, though, 'Oumuamua is on its way out. Having zipped past the Sun and Mars in November 2017, it's set to pass the orbit of Jupiter in May 2018, and reaching Neptune in 2022. There is no chance of sending a probe to meet it because it's going so fast that it will be past the Kuiper Belt's outer edge in seven years time. But its visit has been welcomed and proved very exciting, with astronomers hoping it's the first discovery of many more in the future.

The possibility that 'Oumuamua was an alien spacecraft was seriously raised due to the interstellar asteroid's unusual nature

"It's going so fast that it will be past the Kuiper Belt's outer edge in seven years' time"

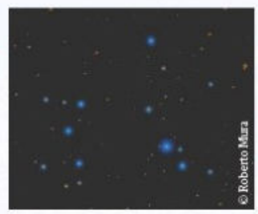
The Pan-STARRS1 telescope was the first to spot 'Oumuamua as it made its way back to outer space

What's in the sky?

In this issue...

Red light friendly
In order to preserve your night vision, you should read our observing guide under red light

3 MAR
Open star cluster IC 2602 is well placed for observation, shining at magnitude 1.9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5 MAR
Conjunction between Venus and Mercury in Pisces

10 MAR
Conjunction between the Moon and Mars in Ophiuchus

10 MAR
The Moon and Mars make a close approach, passing within 3°47' of each other in Ophiuchus

11 MAR
Comet 74P/Smirnova-Chernykh is predicted to reach its brightest, glowing at a magnitude of 12.4 in Leo

11 MAR
The Moon and Saturn make a close approach, passing within 2°13' of each other in Sagittarius

14 MAR
Venus is at dichotomy, appearing as a half phase in the evening sky at magnitude -0.5


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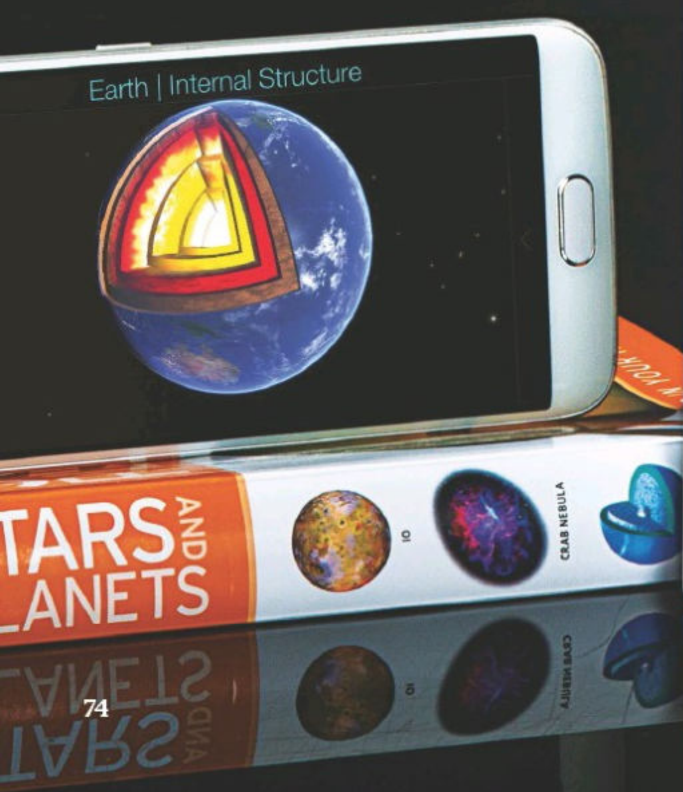
18 MAR
Mars and open cluster NGC 6530 pass within 0°49' of each other in Sagittarius

20 MAR
March equinox



Jargon buster

Conjunction
A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)
This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

7 MAR
Conjunction between the Moon and Jupiter in Libra

7 MAR
The Moon and Jupiter make a close approach, passing within 3°57' of each other in Libra

8 MAR
Open star cluster NGC 3532 is well placed for observation, glowing at magnitude 3.0


©Kevin Heider

11 MAR
Conjunction between the Moon and Saturn in Sagittarius

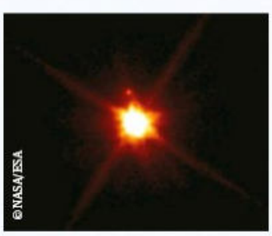

©ESO/G. Beccari

15 MAR
Mercury reaches greatest elongation east and is well placed for observation

18 MAR
Conjunction between Venus and Mercury in Pisces

18 MAR
Conjunction between the Moon and Mercury in Cetus and Pisces

24 MAR
Dwarf planet Makemake is well placed for observation, shining at magnitude 17 in Coma Berenices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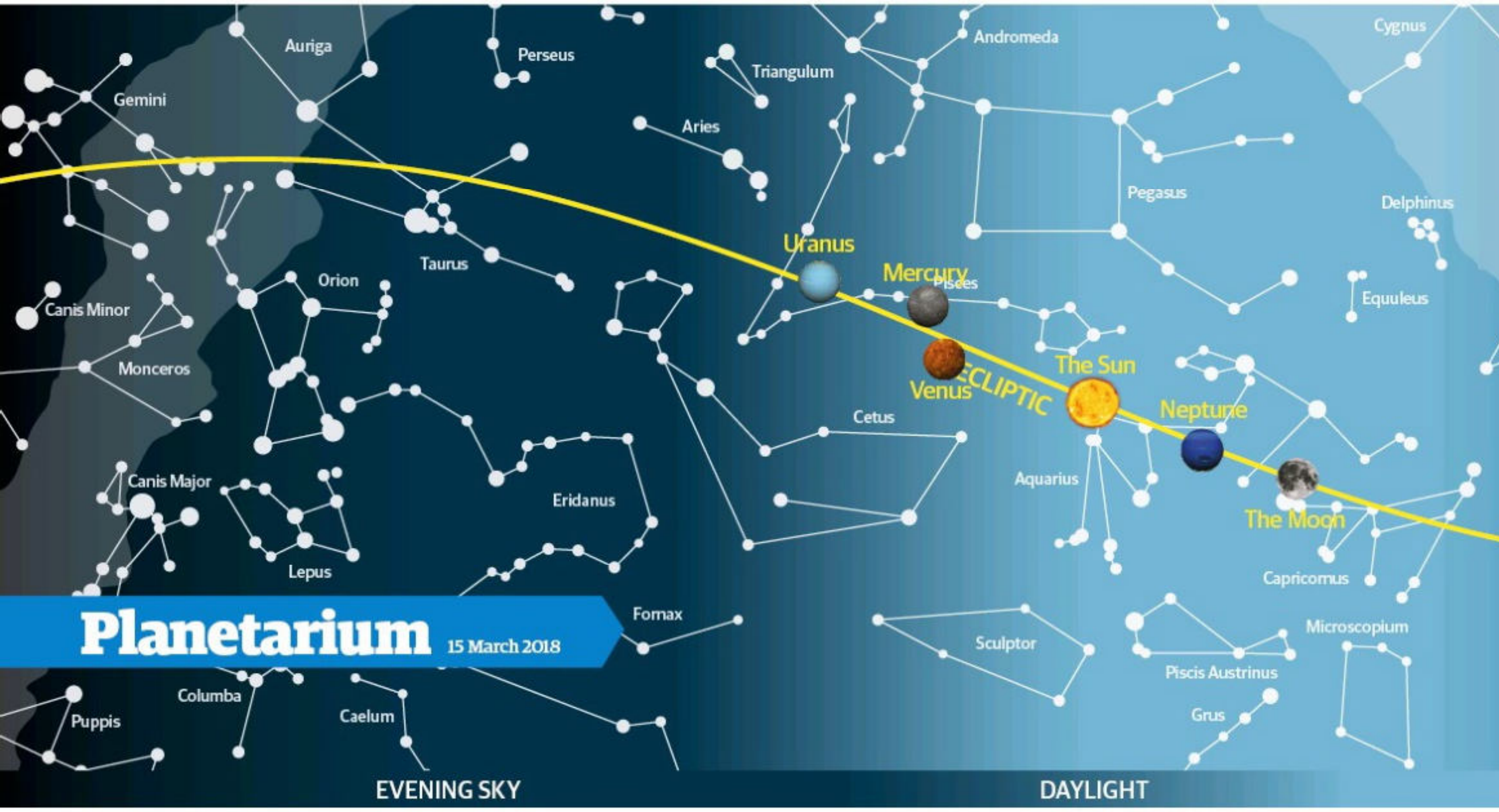
- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope



Planetarium

15 March 2018

Moon calendar

* The Moon does not pass meridian on 1 March

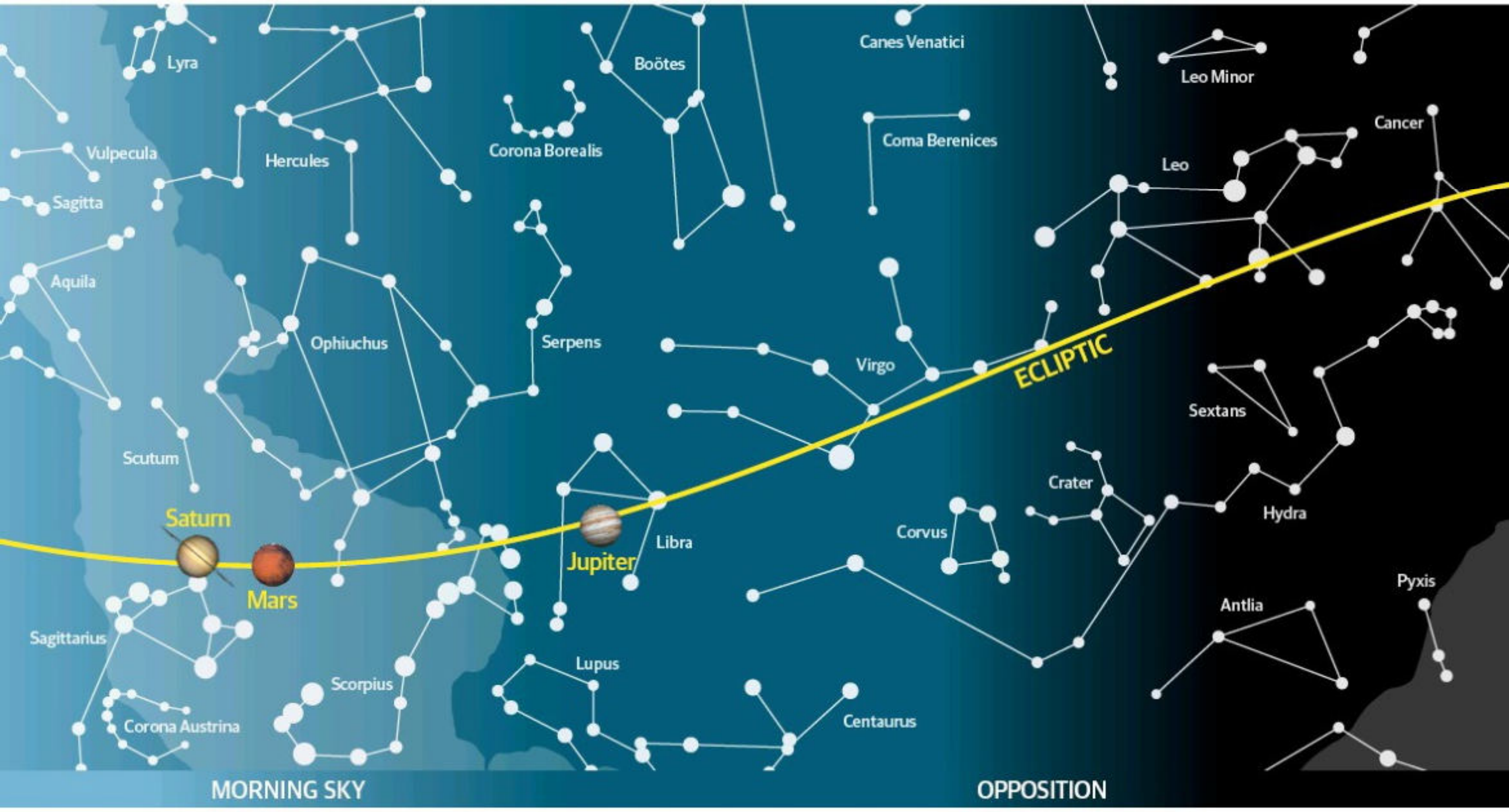
Date	Phase	Illumination	Moonrise time	Moonset time
1 MAR		--.--*%	17:04	06:40
2 MAR	FM	100%	18:23	07:11
3 MAR		98.6%	19:39	07:37
4 MAR		94.6%	20:54	08:02
5 MAR		88.4%	22:05	08:26
6 MAR		80.6%	23:14	08:51
7 MAR		71.7%	-	09:17
8 MAR		62.1%	00:20	09:47
9 MAR	TQ	52.3%	01:22	10:22
10 MAR		42.5%	02:20	11:02
11 MAR		33.1%	03:12	11:48
12 MAR		24.2%	03:57	12:40
13 MAR		16.4%	04:37	13:38
14 MAR		9.7%	05:11	14:41
15 MAR		4.6%	05:40	15:46
16 MAR		1.3%	06:07	16:55
17 MAR	NM	0.1%	06:31	18:04
18 MAR		1.2%	06:54	19:16
19 MAR		4.8%	07:17	20:29
20 MAR		10.7%	07:42	21:43
21 MAR		18.7%	08:10	22:57
22 MAR		28.5%	08:42	--.--
23 MAR		39.6%	09:21	00:11
24 MAR	FQ	51.4%	10:09	01:20
25 MAR		63.2%*	12:06	03:23
26 MAR		74.2%	13:12	04:17
27 MAR		83.9%	14:25	05:02
28 MAR		91.6%	18:08	05:39
29 MAR		96.9%	19:26	06:10

% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

* Clocks go forward one hour

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage

	08 MAR	15 MAR	22 MAR	29 MAR
MERCURY	80%	50%	20%	0%
VENUS	100%	100%	100%	90%
MARS	90%	90%	90%	90%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

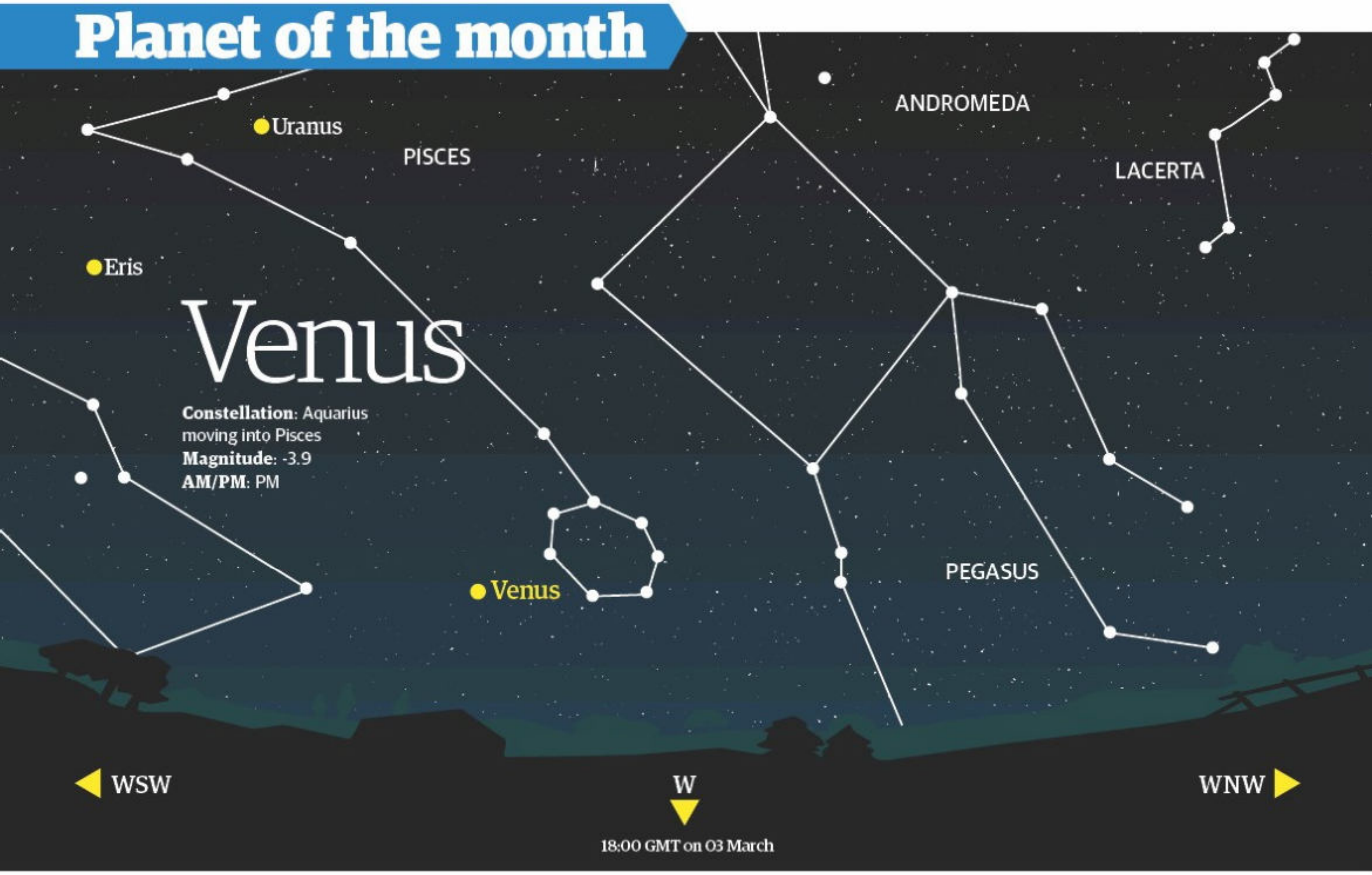
All rise and set times are given in GMT

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	01 Mar	23h 24m 39s	-04° 44' 22"	Aquarius	-1.3	07:08	18:27
	08 Mar	00h 08m 57s	+01° 28' 12"	Pisces	-1.0	06:53	19:15
	15 Mar	00h 42m 22s	+06° 43' 48"	Pisces	-0.4	06:32	19:48
	22 Mar	00h 56m 11s	+09° 27' 55"	Pisces	1.1	06:04	19:48
	29 Mar	00h 48m 17s	+08° 47' 54"	Pisces	4.2	06:32	20:10
VENUS	01 Mar	23h 33m 52s	-04° 18' 46"	Aquarius	-3.9	07:15	18:39
	08 Mar	00h 05m 42s	-00° 44' 11"	Pisces	-3.9	07:01	19:01
	15 Mar	00h 37m 23s	+02° 51' 52"	Pisces	-3.9	06:47	19:23
	22 Mar	01h 09m 10s	+06° 25' 14"	Pisces	-3.9	06:33	19:45
	29 Mar	01h 41m 15s	+09° 51 37"	Pisces	-3.9	07:19	21:08
MARS	01 Mar	17h 16m 36s	-22° 46' 42"	Ophiuchus	0.8	02:43	10:38
	08 Mar	17h 34m 27s	-23° 08' 27"	Ophiuchus	0.7	02:36	10:25
	15 Mar	17h 52m 09s	-23° 23' 20"	Sagittarius	0.6	02:28	10:14
	22 Mar	18h 09m 38s	-23° 31' 40"	Sagittarius	0.5	02:19	10:03
	29 Mar	18h 26m 47s	-23° 33' 52"	Sagittarius	0.3	03:09	10:52
JUPITER	01 Mar	15h 23m 07s	-17° 20' 35"	Libra	-2.2	00:16	09:19
	08 Mar	15h 23m 33s	-17° 21' 04"	Libra	-2.2	23:45	08:52
	15 Mar	15h 23m 22s	-17° 19' 17"	Libra	-2.3	23:17	08:24
	22 Mar	15h 22m 33s	-17° 15' 15"	Libra	-2.3	22:48	07:56
	29 Mar	15h 21m 08s	-17° 09' 04"	Libra	-2.4	00:19	09:23
SATURN	01 Mar	18h 30m 35s	-22° 22' 24"	Sagittarius	0.6	03:54	11:54
	08 Mar	18h 32m 39s	-22° 20' 47"	Sagittarius	0.6	03:29	11:29
	15 Mar	18h 34m 26s	-22° 19' 16"	Sagittarius	0.5	03:03	11:03
	22 Mar	18h 35m 54s	-22° 17' 56"	Sagittarius	0.5	02:37	10:37
	29 Mar	18h 37m 03s	-22° 16' 50"	Sagittarius	0.5	03:10	11:11

This month's planets

Venus is the 'star of the evening' this month, while Mars and Jupiter take the morning watch – a treat for early risers

Planet of the month



Venus

Constellation: Aquarius moving into Pisces
Magnitude: -3.9
AM/PM: PM

Even though Venus will spend the month quite low in the west after sunset, this is still a great month for looking at the "Evening Star" because it is going to have close encounters in the sky with several other worlds, all of which will make great photographic subjects.

At the start of the month Venus will be low in the west after sunset, and as the sky darkens should come into view to the naked eye very easily. You'll also notice another "star" close to it, on its right. This is the planet Mercury, and on the evening of the 3rd the two planets will be just a degree apart. They should look very striking together through binoculars or a small telescope, and photos taken through a zoom lens will show the two planets shining close together like a beautiful double star. In fact, they might even look like a double star to the naked eye for those with good eyesight, a very clear sky and no obstructions to the west.

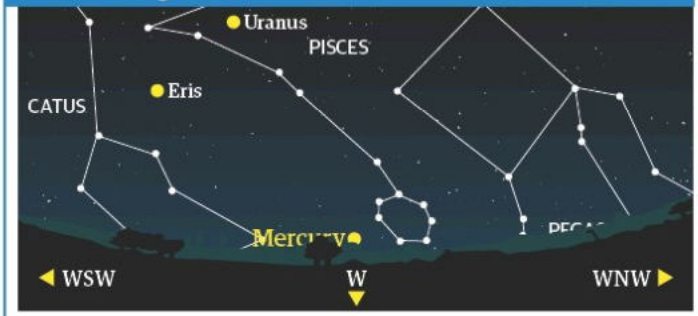
After their close encounter the two planets will begin to drift apart, but Venus will be moving further away from the Sun now, shining a little higher each evening, heading towards its next celestial rendezvous, this time with the Moon.

On the evening of 18 March a lovely sliver of a crescent Moon will be just over four degrees away from Venus. You will need to scan the sky to the lower left of Venus with binoculars to spot the one-day-old Moon, as it will be so thin. The following evening the Moon will have moved on and will be shining ten-and-a-half-degrees away from Venus, to its upper left, but it will be easier to see as its crescent will have grown in size. At this time the dark part of the Moon's face should be starting to glow softly with the subtle lavender-hued light of "Earthshine", and the view west should be very striking indeed.

Having met Mercury and the Moon in the sky, Venus will then head towards its third and final meeting, this time with the distant planet Uranus.

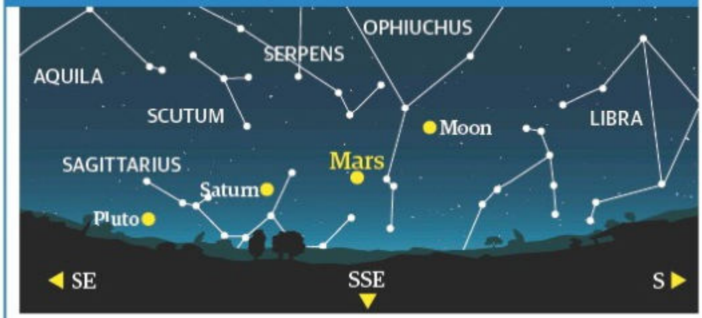
On the evening of 28 March Venus will be just 16 arc minutes away from Uranus. At magnitude 5.9 Uranus is technically a naked-eye object, and if you have super-sharp eyesight you might spot it without any help on this evening, but more likely you'll need to use binoculars. With Venus in the centre of your binoculars' field of view, Uranus will look like a tiny green-white star almost directly above it. They will look close together visually, but of course it will just be a line-of-sight effect: in fact they will be almost 1.8 billion miles apart, which is 19-times the distance between the Sun and the Earth.

Mercury 18:30 GMT on 03 March



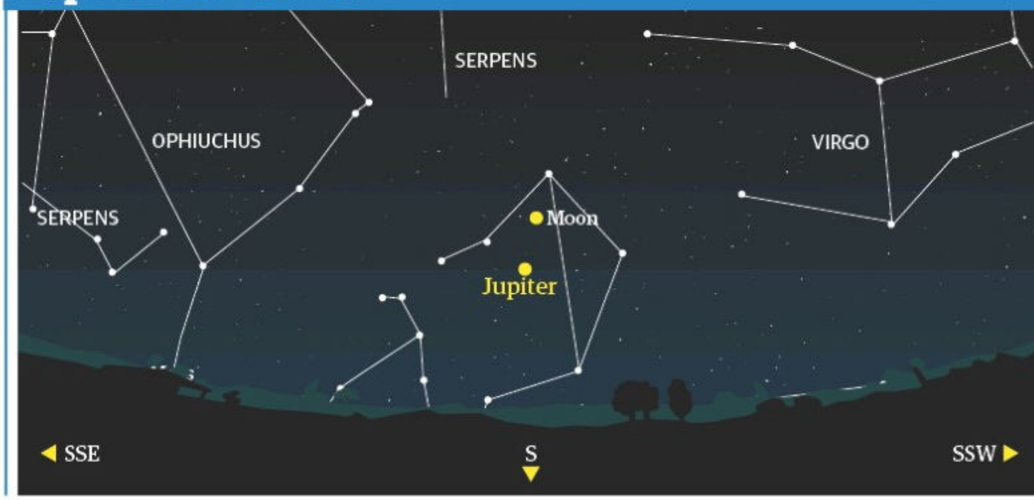
Constellation: Pisces
Magnitude: -1.3
AM/PM: PM
Mercury is easy to observe this month. Start looking for it 20 minutes or so after sunset and you might find it right away, looking like a "star" close to Venus. They will be at their closest during the first few days of the month, and on the evening of 3 March will be shining side by side, just over a degree - or two Moon widths - apart.

Mars 05:30 GMT on 09 March



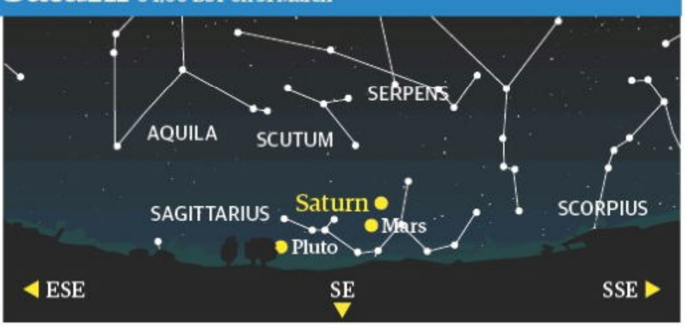
Constellation: Ophiuchus moving into Sagittarius
Magnitude: 0.8
AM/PM: AM
Mars is easily visible to the naked eye this month, shining like an orange star in the south east before sunrise. This month Mars will be between Saturn to its lower left and Jupiter to its upper right, with Saturn making an approach. The waning crescent Moon will pass above Mars between the 9th and 10th.

Jupiter 04:30 GMT on 07 March



Constellation: Libra
Magnitude: -2.2
AM/PM: AM
Jupiter will be dominating the morning sky this month. Shining at magnitude -2.2 will make it immediately obvious to the naked eye as the brightest star-like object in the sky before the Sun comes up, and much brighter than any other planet in the sky, except Venus. Jupiter will be on the far-western end of a line of three planets, with Mars to its lower left and Saturn on the other end of the line to the lower left of Mars. By the end of the month it will actually be rising before midnight, so it will be visible all through the night. Look out for the waning gibbous Moon hanging above Jupiter on the morning of the 7th.

Saturn 04:00 BST on 31 March



Constellation: Sagittarius
Magnitude: 0.6
AM/PM: AM
Saturn will be visible in the morning sky all month, looking like a yellow-hued star. As March passes Saturn and Mars will appear to draw closer together until they are just under two degrees apart on the morning of the 31st, when they will look very striking together, almost like a "double star" in the sky, low in the south east.

Uranus 20:00 BST on 28 March

Constellation: Pisces
Magnitude: 5.9
AM/PM: PM
This month Uranus is high in the west as night falls, and sets around 10pm. The planet Venus will be a great help on the evening of 28 March, when it will lie around half a Moon's width beneath the planet after dark. So look for a greenish star directly above Venus through binoculars on that night and you'll have found Uranus.

©NASA

Top tip!

Look for Menelaus when it is close to the terminator. That's when the crater and its surroundings will look their best.

Moon tour

Menelaus crater

How to find the impact at the end of one of the longest rays on the Moon

Many well-known craters on the Moon are famous for being at the centre of complicated systems of rays. When they were formed, Copernicus, Tycho and Aristarchus all splashed bright rays of debris for huge distances across the lunar surface. Elsewhere on the Moon smaller, lesser-known craters have systems of rays too, and one of them, Menelaus, is the source of possibly one of the longest and brightest rays on the Moon.

Menelaus is a small crater, just 27 kilometres (17 miles) across and barely 3 kilometres (1.9 miles) deep, but when the Moon's phase is just right it is easily visible in binoculars and small telescopes. Slightly oval in shape, it lies on the edge of the low Haemus Mountains, a curving mountain range that can be found on the southern shore of the Sea of Serenity.

Through binoculars the crater is quite unremarkable, little more than a sharp-edged pit blasted out of the ground, looking like the hole a nuclear warhead would leave behind in a cheesy science-fiction film. But no warhead created Menelaus; the crater was blasted out of the Moon by a chunk of solar system debris. The object came in at a shallow angle, resulting in the crater's oval shape. The impact scattered debris all around the crater, and created smaller secondary craters too.

Menelaus also seems to be the source of a single, bright and very long ray that stretches away from it and crosses the whole of the Sea of Serenity, but even though the crater and the ray line up perfectly there is still a lot of debate about the relationship between the two.

Known by some observers as 'The Bessell Ray', because it appears to be superimposed over the small crater Bessell which lies to the north east of Menelaus, this ray is a striking sight at full Moon and easily visible in binoculars. The mystery of the ray's origins probably won't be solved until robot probes or human explorers land on the Moon and can directly compare the ray's material to the material inside Menelaus.

Through a small telescope Menelaus itself shows some interesting detail. Its inner walls are subtly terraced, with multiple small, narrow ledges, and its floor is very hummocky, with many mounds and hills there to observe. If the Moon is in the right phase a telescope will also allow you to see a network of fascinating cracks and troughs in the flat, grey plain of the Sea of Serenity just to the north east of Menelaus, known as 'Rimae Menelaus' ('rimae' means gaps, or fissures). At low magnification they look like scratches on the Moon. Higher magnifications at the right phase of the Moon show a complicated network of criss-crossing features, small pits and troughs.

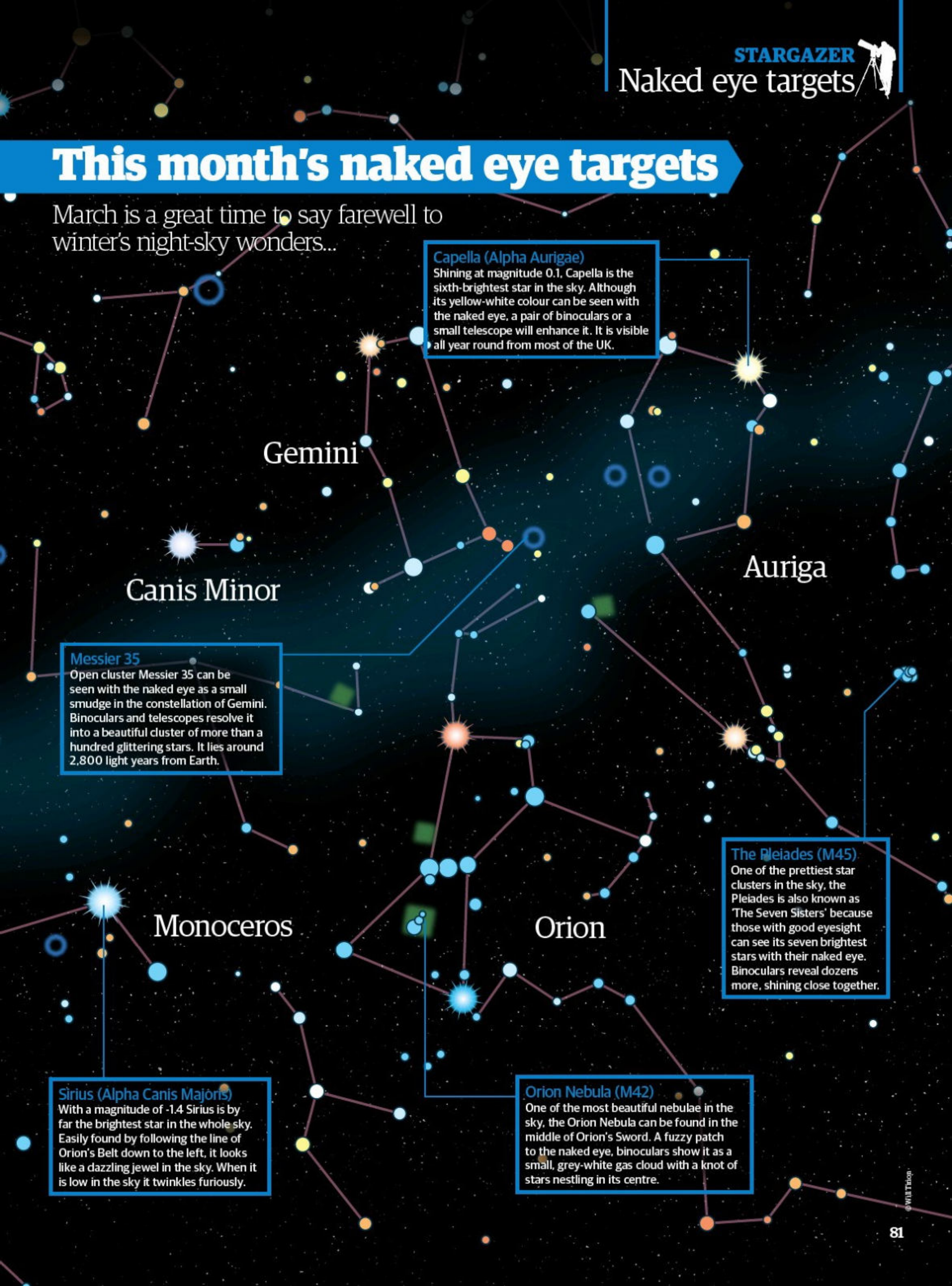
So, when is the best time to see this controversial crater and its fascinating neighbours this month?

At the start of the month the Moon will be full, so Menelaus will be fully illuminated by the Sun and will look like a bright 'spot' on the southern end of Mare Serenitatis, at around the seven o'clock position. By 7 March the crater will be looking like a pit again as the Sun sinks lower in the sky. On the 8th the terminator - the line between day and night - will start to pass across the crater, and it will have vanished from view the following day. Menelaus will then be in total darkness for two long weeks before it reappears on the 23rd as the terminator approaches it once more. The crater will be in full sunlight again by the 24th, and will remain visible until the Moon is full again at the end of the month.

The very best time to see the crater will be between 4 and 6 March, and again between 24 and 26 March, because that's when sunlight will be striking it at a low angle and making it stand out most impressively against the lunar surface.

This month's naked eye targets

March is a great time to say farewell to winter's night-sky wonders...



Capella (Alpha Aurigae)

Shining at magnitude 0.1, Capella is the sixth-brightest star in the sky. Although its yellow-white colour can be seen with the naked eye, a pair of binoculars or a small telescope will enhance it. It is visible all year round from most of the UK.

Messier 35

Open cluster Messier 35 can be seen with the naked eye as a small smudge in the constellation of Gemini. Binoculars and telescopes resolve it into a beautiful cluster of more than a hundred glittering stars. It lies around 2,800 light years from Earth.

The Pleiades (M45)

One of the prettiest star clusters in the sky, the Pleiades is also known as 'The Seven Sisters' because those with good eyesight can see its seven brightest stars with their naked eye. Binoculars reveal dozens more, shining close together.

Sirius (Alpha Canis Majoris)

With a magnitude of -1.4 Sirius is by far the brightest star in the whole sky. Easily found by following the line of Orion's Belt down to the left, it looks like a dazzling jewel in the sky. When it is low in the sky it twinkles furiously.

Orion Nebula (M42)

One of the most beautiful nebulae in the sky, the Orion Nebula can be found in the middle of Orion's Sword. A fuzzy patch to the naked eye, binoculars show it as a small, grey-white gas cloud with a knot of stars nestling in its centre.

How to...

Observe the mysterious Lunar 'X'

A fleeting and therefore seldom-observed feature on the Moon's surface. Once you've seen it you'll understand why it has this name...

You'll need:

- ✔ Telescope
- ✔ Moon map
- ✔ Wristwatch
- ✔ Digital camera (optional)

First discussed on the Internet in the early 2000s, although it may well have been noted by astronomers before then, the Lunar 'X' is a fleeting apparition on the Moon which occurs each month, but only for a few hours.

Because of its transitory nature, it has not been seen by many people. However, it can be observed by anyone armed with even a small telescope or binoculars, if they are well supported, if you know where to look. It is caused by sunlight catching the tops of crater walls during a lunar dawn. It appears as a letter 'X' seemingly emblazoned on the lunar surface, just before the first quarter phase, and is caused by a chiaroscuro effect, in other words a transition between light and dark, once used to great effect by renaissance painters to give solidity to features such as people's faces. In this case it is sunlight catching the highest peaks of crater walls, while the craters themselves remain in deep shadow. The rims and ridges of the craters La Caille, Blanchinus and Purbach are the progenitors of the 'X' when they happen to lay on the terminator.

> "Because of its transitory nature, it has not been seen by many people"

Because the Moon, like the Earth, is moving about the Sun, the lighting conditions on its surface are changing constantly. We see the lit and unlit parts of the Moon as its ever changing phases, while the boundary between the two is known as the terminator. At the first quarter phase, when the Moon is one quarter of its journey around the Earth, taking the 'New' phase, when it is in line with the Sun, as the starting point, the lunar surface is apparently half lit. This can seem confusing at first, but it is just a matter of terminology. It is here on the terminator that the shadows appear longest, and so the features around this line really stand out when viewed through a telescope. It is also a time when the sunlight can catch mountain peaks while leaving the valleys in shadow and so it is that the lunar 'X' is visible for a few short hours. If you want to see it for yourself, then you'll need to look for it around the first quarter Moon.

Tips & tricks

Moon map
Have a good-quality Moon map to hand, as this will help you locate the position of the Lunar 'X'.

Consider binoculars
If you are using binoculars, use a tripod with a mounting bracket to hold them really steady.

Work up to a telescope
You can use practically any size of telescope, but will need a selection of eyepieces to vary the magnification, low power is better for first locating it.

Increase the magnification
Once you know where to look, increase the magnification to bring the Lunar 'X' into comfortable view.

Know your timings
Check the time that the Lunar 'X' should be visible on the Internet before viewing, and check when the first quarter phase is reached.

How to snap a shot of the phenomenon

Once you've seen the Lunar 'X', why not snap a picture of it?

You only have about four hours around the time of the first quarter phase to see the Lunar 'X', otherwise this region looks like any other group of craters on the surface. If when imaging you don't manage to catch it the first time you try, you'll have another opportunity in around 29.5 day's time. This is when the Moon will once again be at its first quarter phase. Good hunting!

Send your photos to
space@spaceanswers.com

1 Moon map

Study your Moon map to see the position of the craters which give rise to the Lunar 'X' near crater 'Werner'.

2 Give yourself plenty of time

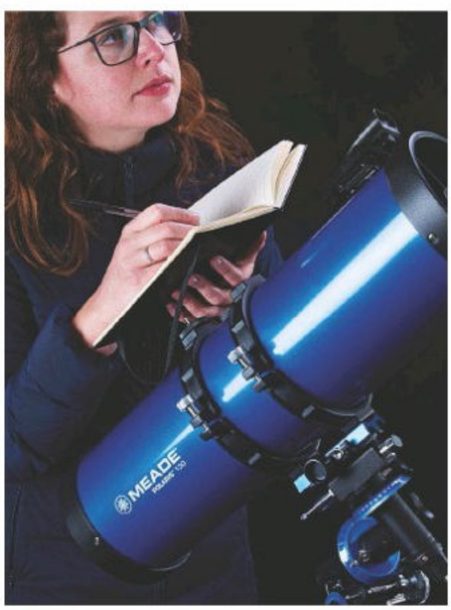
Set up your telescope in good time, before the 'X' is due to appear. Turn on any telescope drives you may have to track the Moon.

3 Go for a lower-power eyepiece

Use a low-power eyepiece to start with to help locate the region of interest, you can increase the power once you've found it.

4 Increase your power

Once you have spotted the 'X', increase the magnification to help make it more obvious in the eyepiece.



5 Take some notes

Make a note of the time you first saw the feature and where on the lunar surface it appeared.

6 Image the region for improved colour and contrast

Try imaging the region to truly bring out its subtle features, even if it's with your smartphone.

NGC 2903

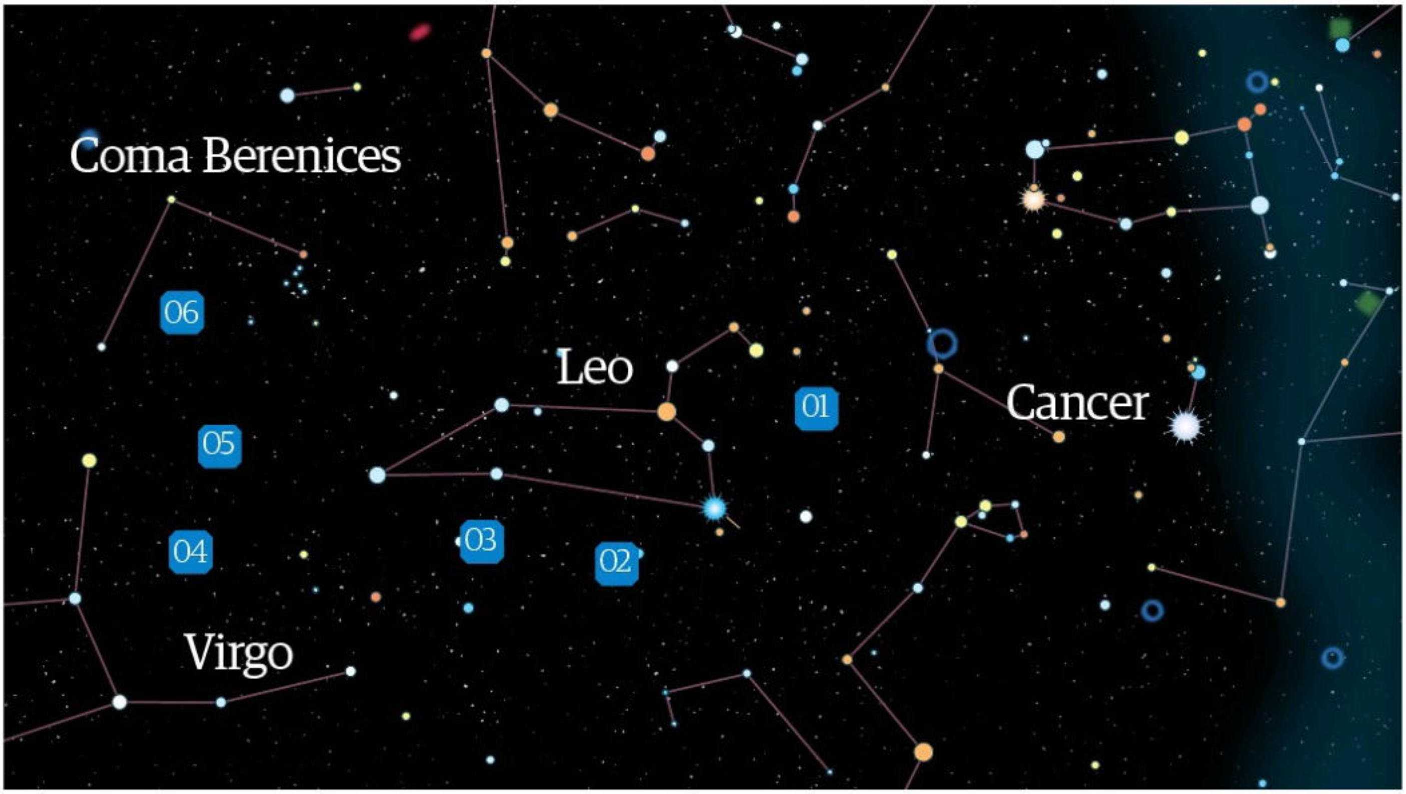
Deep sky challenge

Galaxies of Leo, Coma Berenices and Virgo

The constellations of early spring are prominently on show. Here are some fascinating deep-sky objects for your telescope...

The night skies of early spring are best known for marvellous views of the star clusters and galaxies on offer. We can see galaxies especially well at this time of year due to the Earth facing away from the Milky Way galaxy and out towards the depths of space. The constellations of Leo, Coma Berenices and Virgo are rich hunting grounds for those who like to look out into the far reaches of the universe. There are several bright and well-known galaxies on view, along with many fainter and harder to see objects to push your scope to the limit.

Messier 96




Black Eye Galaxy (Messier 64)

1 NGC 2903

The spiral galaxy NGC 2903 is considered to be 'active' due to the high rate of star birth going on in its core. Observations using modest telescope apertures reveal a bright oval embedded in a haze.

2 Messier 96

Like M95, this galaxy has a spiral structure and can be found in the 'stomach' of Leo. It's said that M96 is of a similar size to the Milky Way at 100,000 light years across.

3 Leo Triplet

Consisting of M65, M66 and NGC 3628, this famous group of galaxies is a popular target for astrophotography. These three large spiral galaxies can be viewed in the same field of view.

4 Messier 49

Under good conditions, a large pair of binoculars - of about 15 x 70 magnification - will reveal this elliptical galaxy's bright core. You'll need a large telescope in order to pick out its halo.

5 Messier 87 (Virgo A)

Messier 87, also dubbed the Smoking Gun, appears as a fuzzy ball of light, elliptical in shape with a bright centre. A jet emanates from the centre, which will require imaging equipment.

6 Black Eye Galaxy (Messier 64)

Messier 64 has a dark dust lane near its nucleus which gives rise to its name. A six-inch telescope will reveal the galaxy as a smooth oval, its dark band more obvious at dark sky sites.

How to...

Capture this month's planetary conjunctions

This March we can see several conjunctions – close approaches of objects to each other in the night sky...

You'll need:

- ✔ DSLR camera
- ✔ Telescope
- ✔ Image processing software

March 2018 will see conjunctions of the Moon with planets, planets with other planets as well as planets with deep-sky objects. All of these will make a wonderful sight, and are great targets for astrophotography. Getting good pictures however, may require some image processing, along with knowing how to set up the shot in the first place.

It can depend where you are on planet Earth for exactly what you see with regards to conjunctions of the Moon and planets. Some approaches can appear very close indeed. For example, the close approach of the planets Venus and Uranus on the evening of the 29th will mean that both objects will fit comfortably in the field of view of most low-power telescope eyepieces. Other conjunctions will appear much wider but can still be framed in the lens of a camera. In order for your camera to register both the Moon and a much fainter planet, you may need to take two images at differing settings and combine these in an image processing package, such as Photoshop or GIMP, to show both objects well. There will be some image processing necessary for conjunctions between a planets and a deep-sky object too. Although the difference in brightness would be less in this case, most deep-sky objects are intrinsically faint and require processing to show them well.

You may be able to use an ordinary camera lens for a wide-field shot, such as the conjunction of the Moon and Venus on the 18th, or a telephoto or zoom lens to frame the shot well. Some of the most dramatic pictures have a foreground, perhaps in silhouette, in the frame. This is of course, entirely up to your own personal taste. For other conjunctions, you will need a telescope and a means of attaching your camera to it to get the best images. Nearly all of these images will require some degree of processing to get them to look their best. You will not have to have great knowledge or experience to get your photographs looking good. Just a few simple routines will enhance your images and give them the 'wow' factor. Follow the tips and steps here to produce images that you can be proud of and record some truly amazing astronomical events.

"Just a few simple routines will enhance your images"

Tips & tricks

Set up before the event

Setting up your camera and other equipment in plenty of time before the event is a must to ensure a good shot.

Try out framing

Do your best to frame your shots. Foreground trees and bushes can really enhance a conjunction image.

Go for manual settings

It's always better to use manual rather than automatic settings on your camera; this will ensure that you can tweak modes to suit your environment or imaging conditions.

Focus is essential

Do your best to get a sharp a focus as possible. Don't just rely on your camera markings.

Avoid over-processing

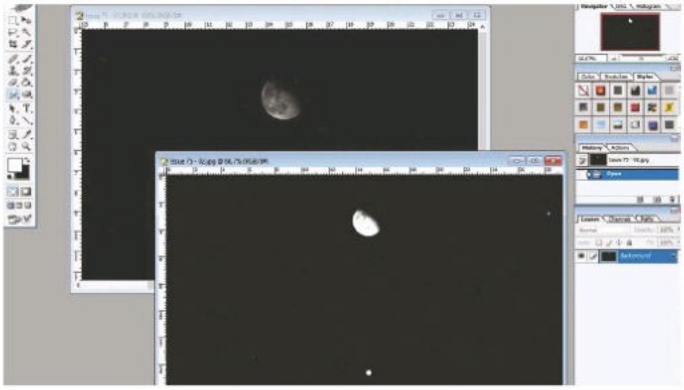
Less is usually more to get a good result, so be mindful of this when it comes to using your chosen software.

How to process your images

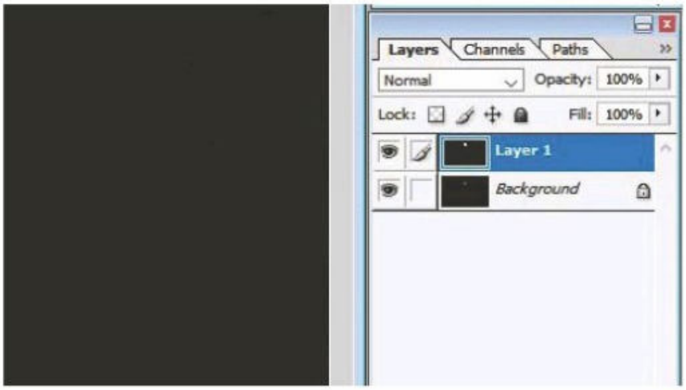
There are several programs in which you can spruce up your conjunction shots...

Photoshop and many other such packages have processes which can convert a dull image into something to be proud of. You can also combine two images together to remove an overexposed Moon or an underexposed planet, for example. By removing the offending object from one image and then combining the images together, you get the best of both in one clear image.

Send your photos to **space@spaceanswers.com**

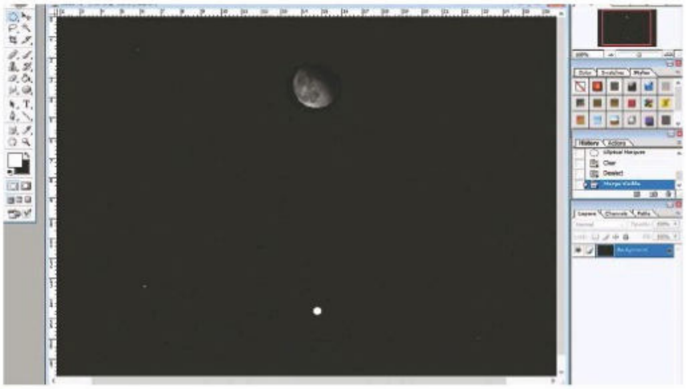


1 Transfer your images to your chosen software
Import your images into some image processing software such as Photoshop or GIMP.

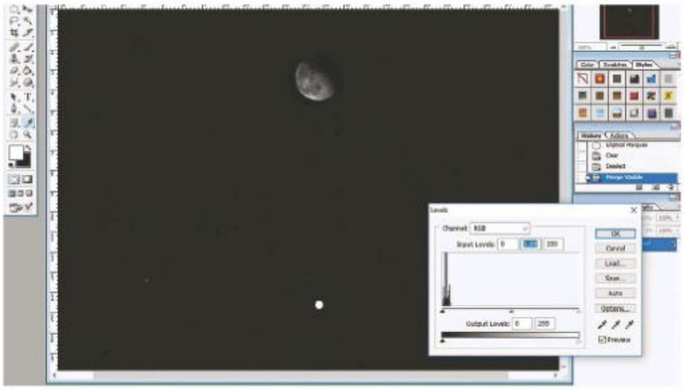


2 Layer your overexposed shots
If you have taken two images of a conjunction, one overexposed, paste the more exposed one over the other.

3 Move onto blending
Using the 'marquee' tool, line it up with the Moon and delete the disc of the Moon from the layer revealing the less exposed version.



4 Flatten your images
Add the two layers together using the 'flatten layers' command, this will combine both versions of your image.



5 Enhance your shot using levels
Using the histogram, sometimes known as 'levels', move the sliders to enhance the fainter parts of the image.

6 Unsharpen the mask
Use the 'unsharp mask' from the 'filters' menu to bring out detail, but don't overdo it!

The Northern Hemisphere

We're in the full swing of spring, where Orion fades to the south west while Leo climbs from the east

Leo (the Lion) takes pride of place in the night sky, cutting a regal figure as its leading star – hot, blue Regulus – shines at magnitude 1.36, making it an unmissable sight. Galaxies are also in abundance here – from the spiral arms of Messier 95 to the featureless, yet prominent form of Messier 105 – as well as a selection of binary stars, including Rho Leonis.

Leo is bordered by Cancer, Coma Berenices, Crater, Hydra, Leo Minor, Lynx, Sextans, Ursa Major and Virgo, the latter of which also offers a selection of galaxies to be enjoyed. However, if your interests lie in tracking down spring's nebulae and star clusters, head over to the Great Bear for the Owl Nebula or the Beehive Cluster, also known as Praesepe, in the Crab.

Using the sky chart

This chart is for use at 10pm (GMT) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

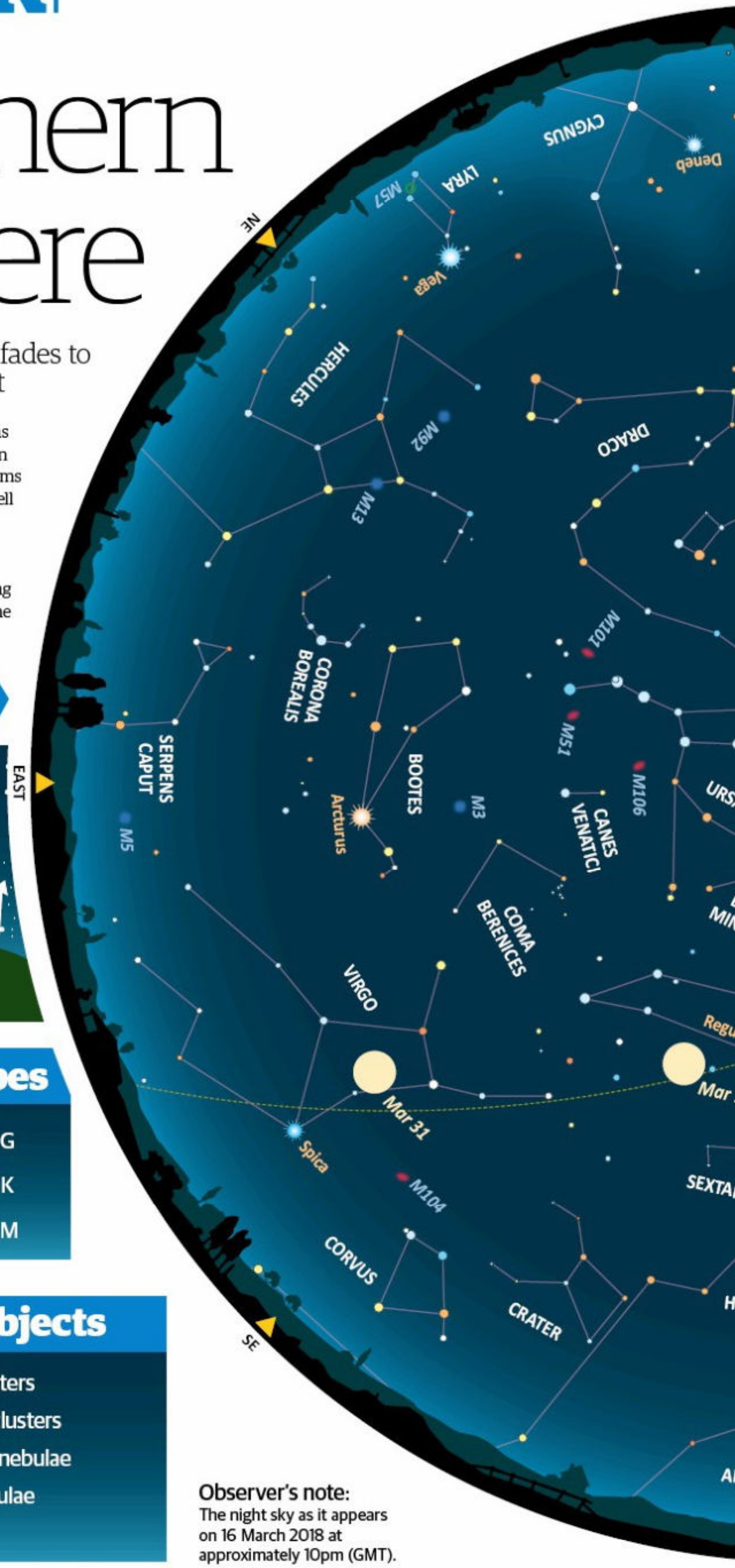
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

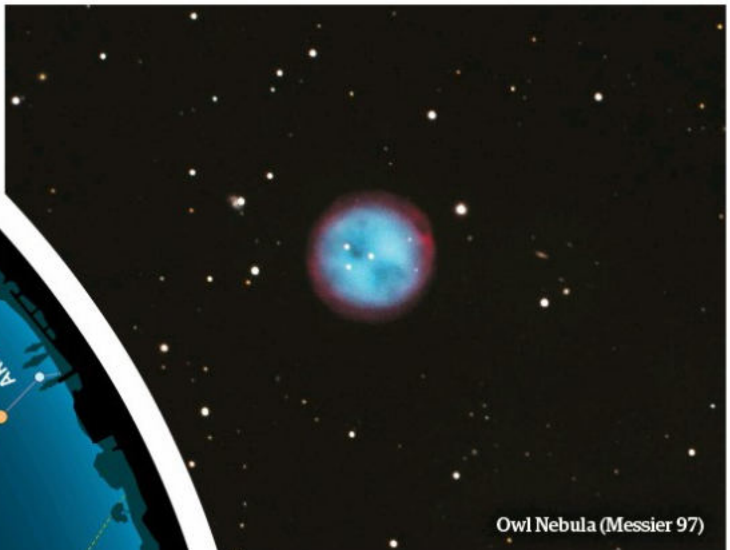
- O-B
- A
- F
- G
- K
- M

Deep-sky objects

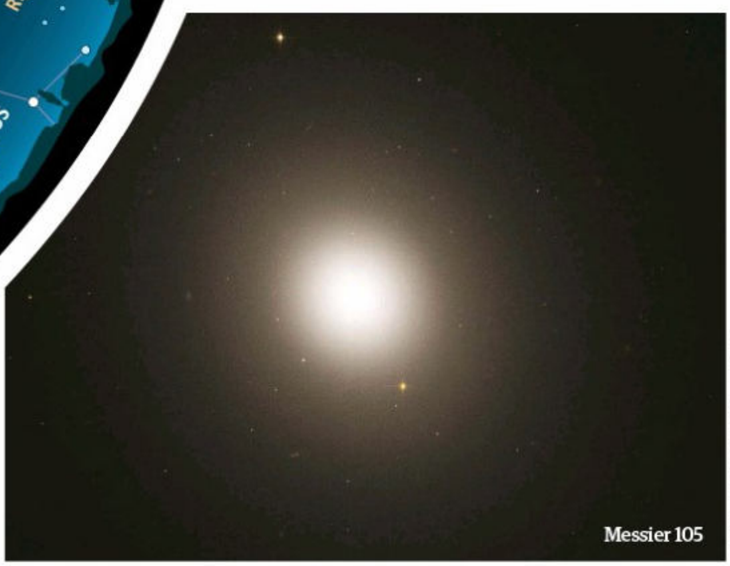
- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:
The night sky as it appears on 16 March 2018 at approximately 10pm (GMT).


Owl Nebula (Messier 97)


Messier 66


Messier 105

Astroshots *of the month*

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**

Jeff Johnson

Las Cruces, New Mexico

"Some of my last data from my camera. Here's a closer look at supergiant star, Sadr (also known as Gamma Cygni) in the constellation of Cygnus. A bright white-blue star at the centre of this image, the diffuse emission nebula IC 1318 lies in the background and appears red and quite dark in colour."

Gamma Cygni

Peter Louer

Teide National Park, Tenerife

"I retired to the beautiful island of Tenerife in 2013. One of the top sites in the world for astronomy, the Caldera in Teide National Park is at an altitude of over 2,000 metres, with a dry atmosphere and limited light pollution, it has proved to be the ideal location to combine my hobbies of photography and astronomy. Here is a shot of the Orion Nebula (Messier 42), the Horsehead Nebula (Barnard 33) and the Running Man Nebula (Sh2-279) in the constellation of the Hunter; a true pleasure to image at such a fine location."

Orion Nebula (Messier 42)

Adam Tatton-Reid

Brecon Beacons, Wales

"I love the outdoors. Having the stunning Brecon Beacons on my doorstep means that I have plenty of reasons to share the beautiful countryside through my photographs. I enjoy astrophotography on occasion; it gives me some interesting opportunities to stretch my photographic abilities, just like these shots of the dusty path of the Milky Way snaking above the Welsh landscape."

Send your photos to... @spaceanswers space@spaceanswers.com

Sky-Watcher Skymax-102 (AZ-EQ AVANT)

The already popular Maksutov is back with a brand-new mount and maintains the features we have come to love with the Sky-Watcher brand

The Maksutov-Cassegrain design allows for a long focal length in a compact telescope tube

Telescope advice

Cost: £315.00 (approx $448.00)
From: Optical Vision Ltd
Type: Maksutov-Cassegrain
Aperture: 4"
Focal length: 51"

Best for...

- Beginners
- Medium budget
- Planetary viewing
- Lunar viewing
- Bright deep-sky objects

March has arrived, signalling the end of the annual prime time observing period. The nights are getting shorter, but that doesn't mean you can't have as much fun. Especially when Sky-Watcher have now fitted a brand-new AZ-EQ AVANT mount on to a fan-favourite Skymax-102 beginners telescope. With a mount that can be controlled with both alt-azimuth and equatorial configurations, a host of new possibilities await with the combination of this already impressive Maksutov-Cassegrain telescope.

To start with, it may be best to know what is included with this kit. The main elements of the bundle include a sturdy tripod, capable of expanding to 1.5 metres (five foot) with the new, well-engineered AZ-EQ AVANT mount, and the Skymax-102 telescope itself, with a focal ratio of f/12.74. Accompanying instruments also include a tripod accessory tray, a 21-centimetre (8.3-inch) extension tube, 90-degree star diagonal, a one kilogram (2.2-pound) counterweight, a red dot finderscope and two Sky-Watcher Super eyepieces, one 10 and one 25 millimetre. What doesn't come in the bundle, but we would highly recommend purchasing, are two of Sky-Watcher's slow motion flexible handles. This would allow for more controlled movement of the mount while navigating around the celestial sphere.

The telescope has been largely advertised as compact, lightweight and easily assembled. After erecting the telescope ourselves, we were impressed with how lightweight it was, making it easy to transport. The telescope tube in particular is very compact, and the overall weight of the telescope adds up to just eight kilograms (17.6 pounds), which makes it ideal for hauling equipment around from field to field. When someone first gets their telescope, arguably the first thing they're going to think is: 'how easy is it to set up?'. In this case, it is essentially trouble-free. Not only is it clearly described in the manual, but also with only four main components, the task is not complex or demanding.

The main aspect of this telescope is the AZ-EQ AVANT mount, which is a new addition to the Sky-Watcher telescopes. This mount is now able to employ both alt-azimuth mount movement, which is simple horizontal and vertical rotation, and equatorial movement, which can navigate through the right ascension and declination axes. Both of these modes have their own advantages: alt-azimuth allows for simple and easy movement of the mount, whereas equatorial is better suited to tracking a star's movement as it rotates around the north star/south star. With both options at your disposal, it can also help you get used to setting-up and using an equatorial mount.

The Skymax-102 is a good, solid starter telescope. Its Maksutov-Cassegrain design allows for a long focal length when focusing the light from a celestial object. The long focal length is what gives the telescope its high focal ratio, which has its benefits, but also its disadvantages. The main advantage is that it is excellent for bright celestial objects, such as lunar and planetary observations. When observing these types of targets, the high focal ratio generates crisp and contrasting images – which will be explained further shortly. On

The optics are best suited for the brightest celestial objects

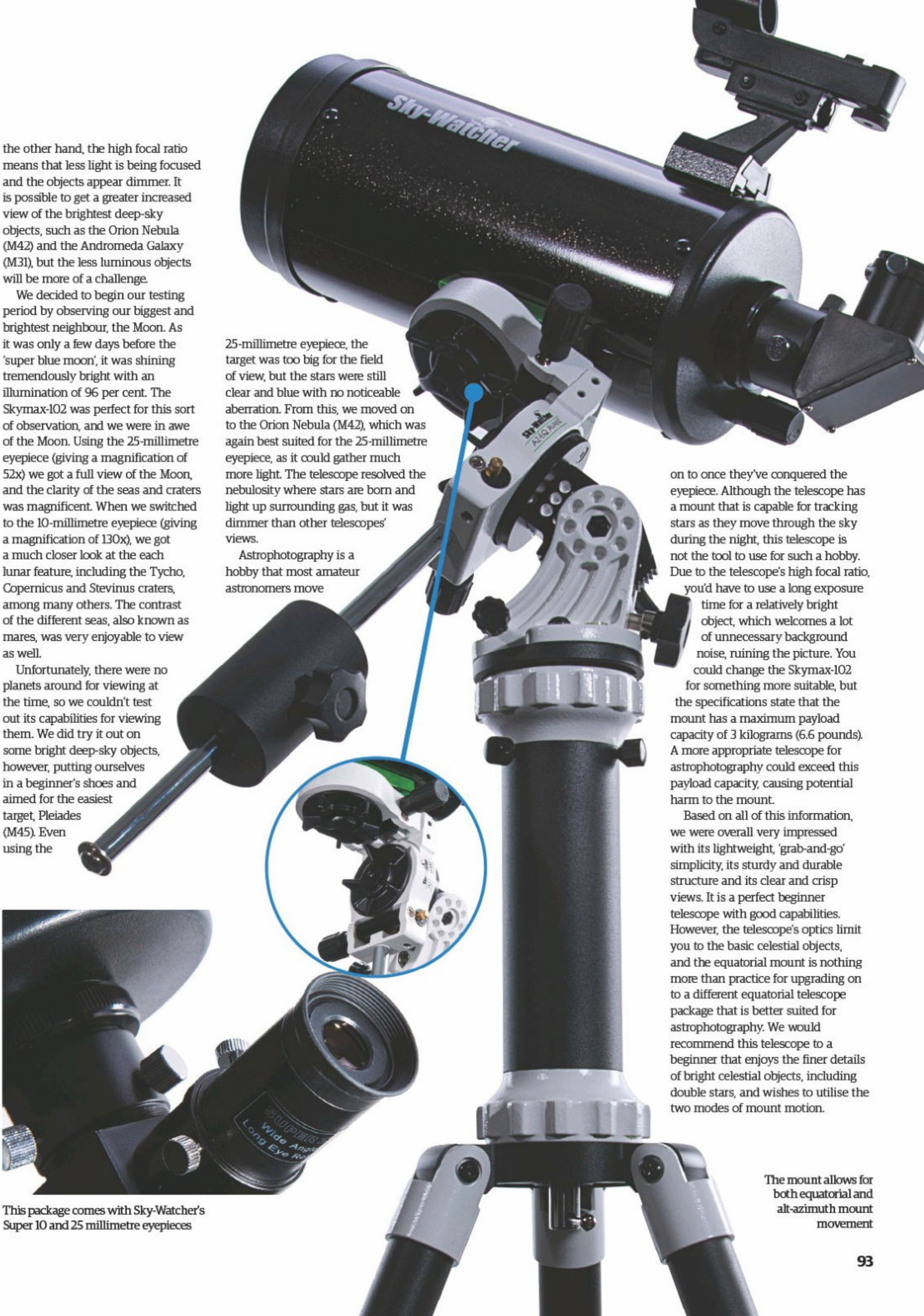
the other hand, the high focal ratio means that less light is being focused and the objects appear dimmer. It is possible to get a greater increased view of the brightest deep-sky objects, such as the Orion Nebula (M42) and the Andromeda Galaxy (M31), but the less luminous objects will be more of a challenge.

We decided to begin our testing period by observing our biggest and brightest neighbour, the Moon. As it was only a few days before the 'super blue moon', it was shining tremendously bright with an illumination of 96 per cent. The Skymax-102 was perfect for this sort of observation, and we were in awe of the Moon. Using the 25-millimetre eyepiece (giving a magnification of 52x) we got a full view of the Moon, and the clarity of the seas and craters was magnificent. When we switched to the 10-millimetre eyepiece (giving a magnification of 130x), we got a much closer look at the each lunar feature, including the Tycho, Copernicus and Stevinus craters, among many others. The contrast of the different seas, also known as mares, was very enjoyable to view as well.

Unfortunately, there were no planets around for viewing at the time, so we couldn't test out its capabilities for viewing them. We did try it out on some bright deep-sky objects, however, putting ourselves in a beginner's shoes and aimed for the easiest target, Pleiades (M45). Even using the 25-millimetre eyepiece, the target was too big for the field of view, but the stars were still clear and blue with no noticeable aberration. From this, we moved on to the Orion Nebula (M42), which was again best suited for the 25-millimetre eyepiece, as it could gather much more light. The telescope resolved the nebulosity where stars are born and light up surrounding gas, but it was dimmer than other telescopes' views.

Astrophotography is a hobby that most amateur astronomers move on to once they've conquered the eyepiece. Although the telescope has a mount that is capable for tracking stars as they move through the sky during the night, this telescope is not the tool to use for such a hobby. Due to the telescope's high focal ratio, you'd have to use a long exposure time for a relatively bright object, which welcomes a lot of unnecessary background noise, ruining the picture. You could change the Skymax-102 for something more suitable, but the specifications state that the mount has a maximum payload capacity of 3 kilograms (6.6 pounds). A more appropriate telescope for astrophotography could exceed this payload capacity, causing potential harm to the mount.

Based on all of this information, we were overall very impressed with its lightweight, 'grab-and-go' simplicity, its sturdy and durable structure and its clear and crisp views. It is a perfect beginner telescope with good capabilities. However, the telescope's optics limit you to the basic celestial objects, and the equatorial mount is nothing more than practice for upgrading on to a different equatorial telescope package that is better suited for astrophotography. We would recommend this telescope to a beginner that enjoys the finer details of bright celestial objects, including double stars, and wishes to utilise the two modes of mount motion.



The mount allows for both equatorial and alt-azimuth mount movement

This package comes with Sky-Watcher's Super 10 and 25 millimetre eyepieces

WIN!

AN ALTAIR ASTRO GPCAM2 290C COLOUR CAMERA

Image the wonders of the cosmos with this compact CMOS

WORTH £239

With spring here, it's time to get creative with this incredible colour camera. You can photograph all your personal favourites, including the Sun, the planets, the Moon, take part in wide-angle time-lapse imaging or even shoot some marvellous deep-sky objects.

The Sony Exmor IMX290 CMOS sensor provides a high sensitivity and low read noise, resulting in crisp images of your favourite objects. Maybe you'll turn it to the Flaming Star Nebula situated in the constellation of Auriga; the colour contrast of the nebula can render inspiring results, or perhaps you'll pick out the craters along the terminator of the rugged lunar surface.

Simply replace your eyepiece with the camera and then connect it to a Windows laptop via a USB 2.0 cable. This data transfer is swift and much improved from the GPCAM1 series, perfect for the astronomer that wants a new challenge.

To be in with a chance of winning, all you have to do is answer this question:

According to modern cosmology, what percentage of the universe is made up of dark energy?

A: 4.9% B: 26.8% C: 68.3%

Congratulations to Adrian Hobbs, who is the winner of the Meade LightBridge Mini 130 telescope

Enter via email at **space@spaceanswers.com** or by post to **All About Space competitions, Richmond House, 33 Richmond Hill, Bournemouth, BH2 6EZ**

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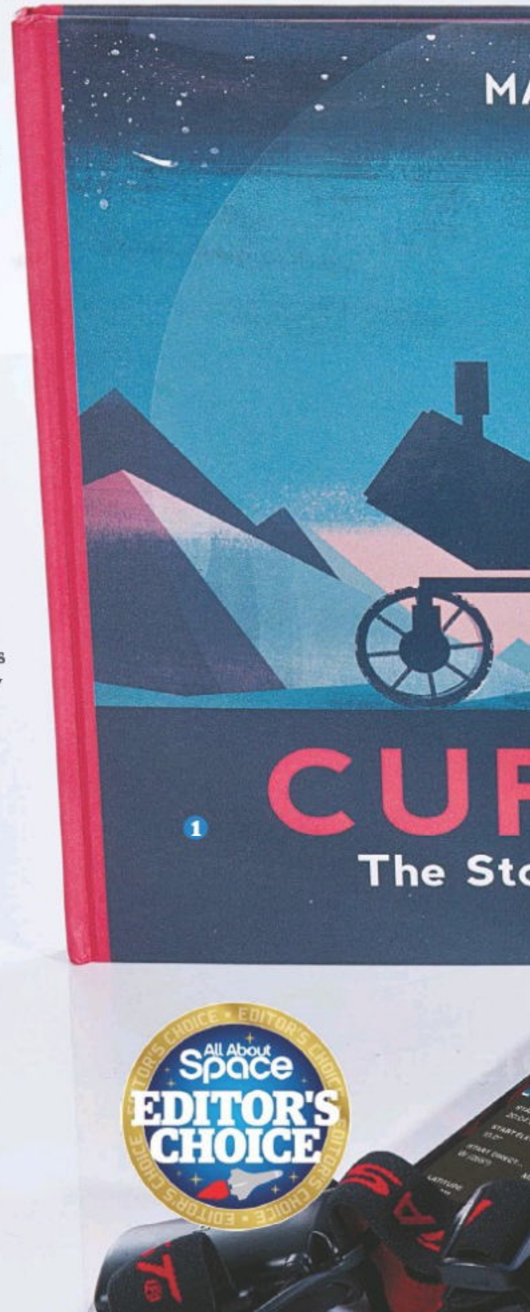
The latest books, apps, software, tech and accessories for space and astronomy fans alike



❶ Book Curiosity

Cost: £15.00 (approx. $21.00) **From:** Walker Books Ltd

Curiosity: The Story of a Mars Rover condenses, illustrates and narrates the long journey of NASA's Curiosity rover. This book, marketed for the ages of six and over, starts by asking the ever-present question 'is anybody else out there?' and continues by explaining how this continual curiosity led to the construction and execution of its namesake rover.

Walker Books is renowned for publishing well-designed and informative children's books, and this publication is exactly what you would expect in quality. It's large, with excellent illustrations and minimal text. It is common knowledge that children pay most attention to the pictures, and the illustrations in this book are the highlight. The colourful, complementary and imaginative pictures will grab the shortest of attention spans. There are a few pages where the annotations are overindulged, which is a minor shame.

A range of information is involved between the covers, which hopefully inspires a newly found love for space exploration, astronomy and a spirit for enquiry in many.

❷ Program Voyager 4.5

Cost: Ranging from £70 to £127 ($99 to $180) **From:** Carina Software

Many amateur astronomers like to plan ahead before they venture out into the cold dark nights for an observing session. Although it's not all-important, it helps utilise time, especially if the area is renowned for its cloudy nature. Voyager 4.5 could help you with this, as it's a sky simulation software package with many great aspects.

You can enjoy the magnificent sights of the cosmos from your desk chair, including the planets, stars and a variety of deep-sky objects. The catalogue of objects in this program is vast and very impressive, and it uses an easy navigation interface. The software can also be used to control a number of telescopes, assuming they are fitted with the appropriate computerised mount, including Celestron, Meade and others.

Enjoyable, knowledgeable and straightforward are some of the words best suited for this program, but the price tag can be a deal-breaker. The cheapest option is $99 (£70), which is the online download, but prices increase if you wish to purchase a CD or DVD set. We recommend that you download the demo, which is available on their website **carinasoft.com**, before making any purchase to get an idea of its capabilities.

❸ Accessories Coast HL4 LED Dual Colour Head Torch

Cost: £19.50 (approx. $27.50) **From:** Rother Valley Optics Ltd

Constructing something in the dark is never fun for anybody; it can be frustrating, time-consuming and just plain annoying, especially when you're assembling your telescope. This is why sometimes an astronomer's best friend can be a headtorch. Even though a pitch-black night means you can really examine the faintest of celestial objects, it can make for quite a problem when setting up your equipment. It takes between 20 and 45 minutes for your eyes to adjust to the dark.

The Coast HL4 LED Head Torch is a perfect fit to help anyone at nighttime, as it has the option between a red or white light. The red light is the best selection when you're observing, as it doesn't ruin your night vision. There are five white LED's compared to one red LED making for a greater illumination if needed. It sits very comfortably on a person's head, and includes the battery pack at the back, keeping them warm enough to ensure that there's longlasting power when required throughout your observations of the night sky.

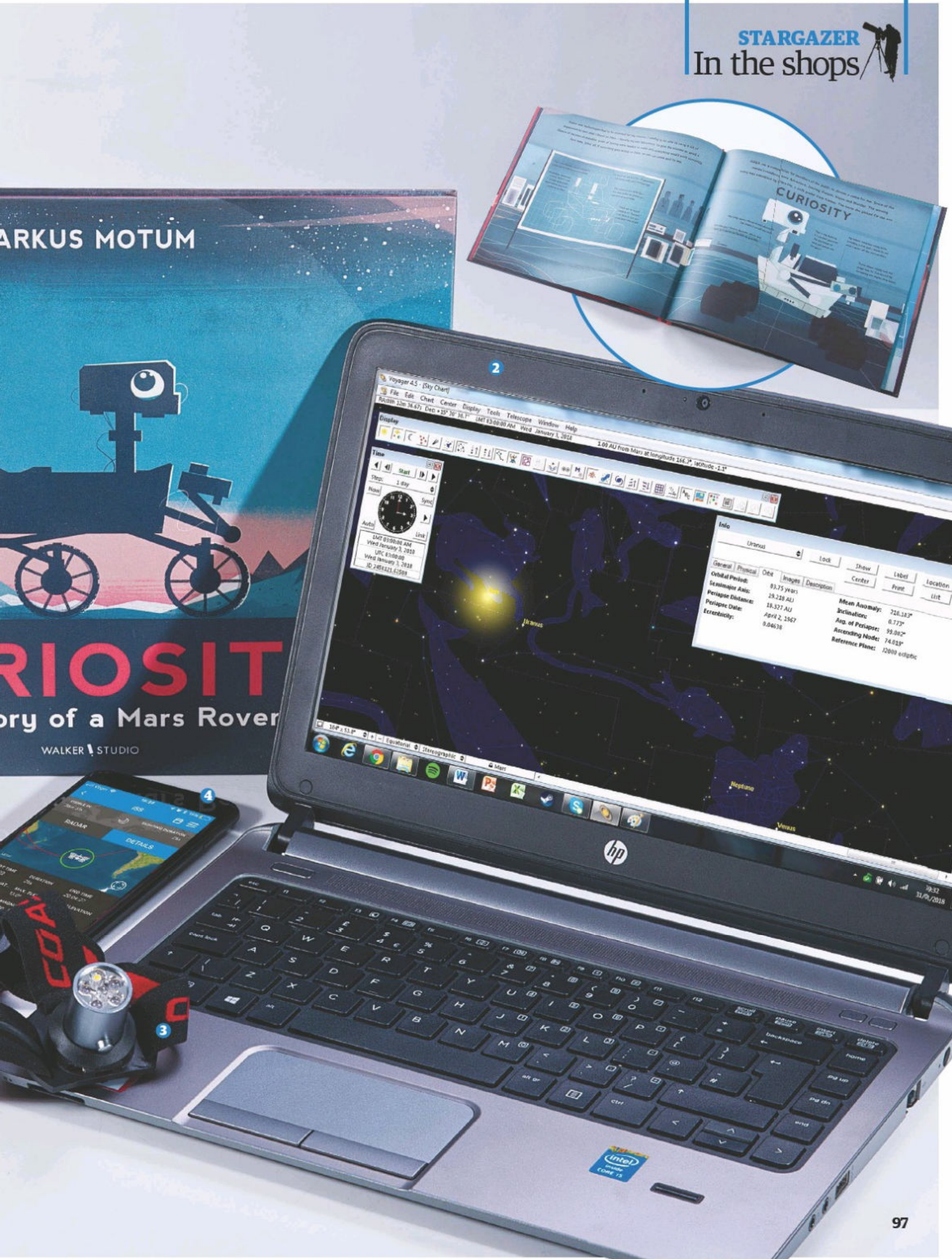
❹ App ISS Detector

Cost: Free **For:** Android and iOS

The International Space Station (ISS) is a majestic habitable satellite orbiting the Earth roughly 400 kilometres (249 miles) away. It is a testament to international cooperation and, more importantly, human spaceflight. It travels around our planet at an extraordinary 27,600 kilometres per hour (17,200 miles per hour) and completes over 15 orbits of the Earth per day!

Because of this fantastic speed and the distance it covers, it is forever passing over our heads. It is one thing to see an aeroplane go hurtling through the sky, but to see a 108-metre (356-foot) Space Station pass by on its constant journey is something else! For this reason, we would recommend this app to anyone who wants to see a satellite containing at least three of the world's finest astronauts whizz past.

The app will use your current location and the known trajectory of the ISS to notify you of when the Space Station will make a visit overhead. With access through android and iOS devices, the ISS Detector will keep you updated and informed as to the ISS' location and visibility details.


ARKUS MOTUM
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WALKER STUDIO
CURIOSITY
2
3
4
Voyager 4.5 - [Sky Chart]
Uranus
Neptune
Venus

HEROES OF SPACE

Margaret Burbidge

She was able to excel in astronomy while fighting for equality

Margaret was influential in our understanding of stellar physics

© Michael Webb/ Stringer

In a time where women were heavily suppressed and couldn't strive in science, Margaret Burbidge was not halted, and had a tremendous career in astronomy. Her work on the chemical composition within stars, the rotation and masses of galaxies and quasi-stellar objects (quasars) spectroscopy has proved to be vital in astrophysics.

Born on 12 August 1919, in Davenport, England, Burbridge grew up having a strong attraction to mathematics and astronomy. As she relocated to London at an early age, Burbridge eventually attended the University College of London where she graduated with a First Class Honours bachelor's degree in astronomy in 1939. This continued with the pursuit of a PhD, which she gained in 1942 while being a caretaker for the university's observatory. Her caretaker duties came as a result of the World War II upheaval that was terrorising the streets of London, especially as many of the observatory's leaders were called up to the military.

After the war ended, Burbridge carried on with her fantastic efforts in astronomical research, eventually taking the roles of assistant director and acting director of the observatory in the late 1940s. In 1951, the Yerkes Observatory in Williams Bay, Wisconsin, United States offered her a grant to continue her studies there. She was there for two years studying the chemical abundances within stars along with her husband, Geoffrey Burbridge.

They both returned to England in 1953, where they developed their most influential paper along with William Fowler and Fred Hoyle. This paper, the B2FH paper, was named after the four authors, and it was a landmark in stellar physics. This work analysed several key processes in producing elements other than hydrogen in a star's interior. They stated that these elements - the elements responsible for making up everything we see before us - are originally produced from the burning within stars, also known as stellar nucleosynthesis. This is a theory that is widely accepted throughout the astronomical community, and it stemmed from this fantastic work done by Margaret and her collaborators.

Margaret's career continued to flourish with a long list of administrative and teaching roles in many highly respected institutions, including the University of California, San Diego, the Cavendish Laboratory at the University of Cambridge, England, the California Institute of Technology and, most prestigiously, she became the director of the Royal Greenwich Observatory in 1972. Four years after she also made history as she became the first female president of the American Astronomy Society.

> "She made valuable movements which have since paved the way for women in astronomy"

This did not come without its struggles though, and she fought valiantly against discrimination to women in astronomy. Noticeably in 1972, she turned down the American Astronomical Society's Annie J. Cannon Award, as it was only presented to women. She made many valuable movements which have since paved the way for woman in astronomy

Margaret's amazing contribution to science and astronomy hasn't gone unrecognised; she has been bestowed with some amazing awards, including the Bruce Medal in 1982, awarded for outstanding lifetime contributions to astronomy. She was also presented the National Medal of Science in 1983 by President Ronald Reagan and the Albert Einstein World Award of Science in 1988.

All About Space

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• Eyepieces Supplied 10mm & 25mm
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• Magnifications (with eyepieces supplied) x48, x96, x120, x240
• Highest Practical Power (Potential) x300
• Diameter of Primary Mirror 150mm
• Telescope Focal Length 1200mm (f/8)
• Eyepieces Supplied 10mm & 25mm
• x2 Deluxe Barlow Lens
• 6x30 Finderscope
• Parabolic Primary Mirror
• 0.5mm Ultra-Thin Secondary Mirror Supports
• Fully GO-TO Upgradeable
• EQ3-2 Equatorial Mount with Aluminium Tripod
• 33% more Light Gathering than 130mm
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